THE KALAHARI, OR THIRSTLAND REDEMPTION.

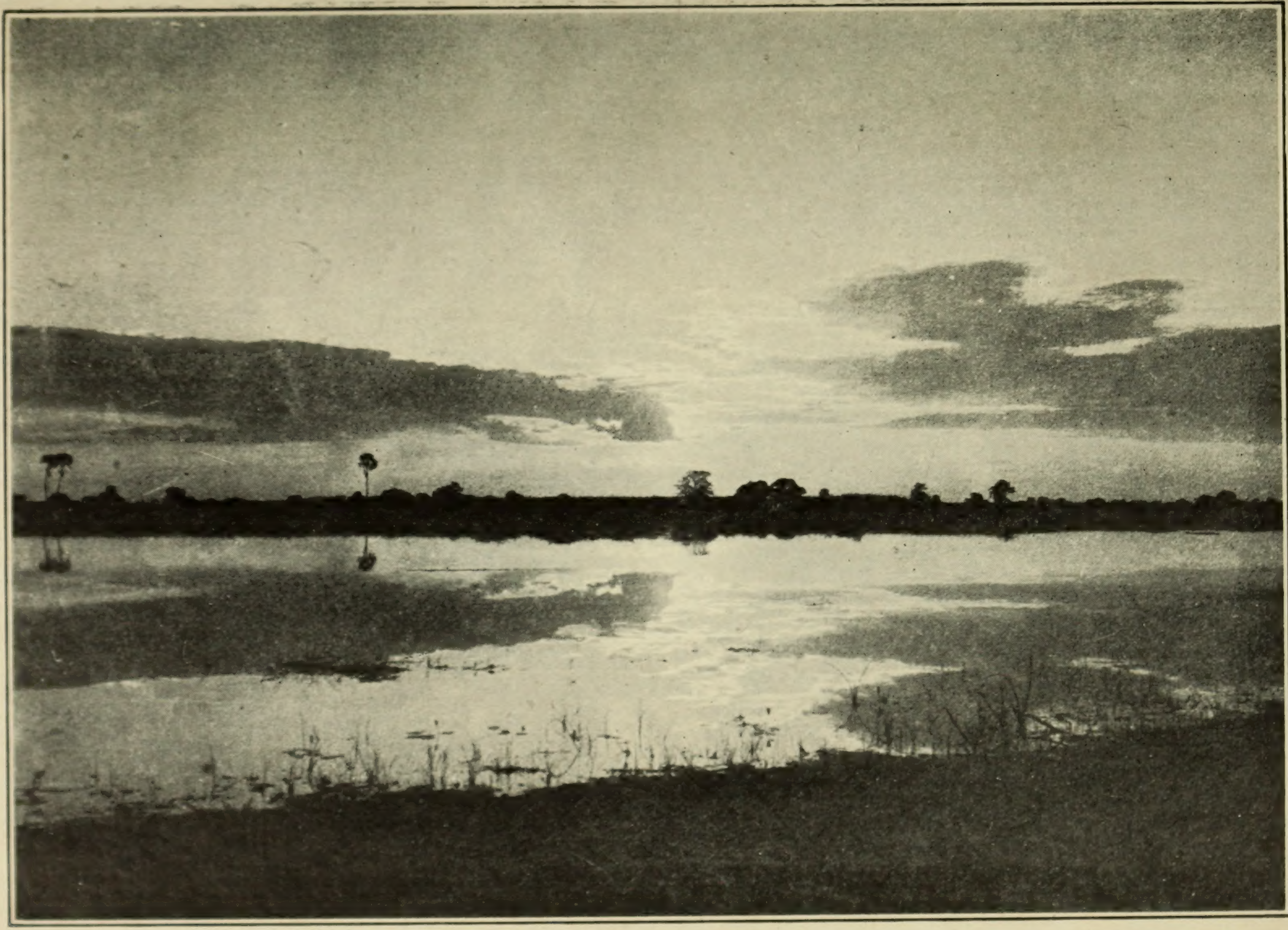

Photo. by] **THE EFUNJA.** [Lieut. C. H. L. Hahn.

Flood-time in Ovamboland; photograph taken in front of the Residency, Ondongua.

THE KALAHARI

OR

THIRSTLAND REDEMPTION

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INTRODUCTION.

The Kalahari Scheme grew out of a chapter on the Geography of Africa that I was writing; in this chapter I reviewed the whole water-system of Africa, and found that, whether dealing with the Niger, the Nile, the Congo, or the Zambesi, one principle ran throughout. This was that the original drainage that at one time used to supply the interior of the continent, was being reft or had been reft, by the more vigorous streams on the coast. In the case of the Zambesi, it became clear that the Cunene and the Zambesi itself were hurrying away to the sea, water that at one time had flowed into the Kalahari, and had made the centre of South Africa fertile. The importance of this became at once apparent, and I talked about the scheme with my friends. I found, however, a reluctance to accept such a vast project, which would alter the face of South Africa, and make it a habitable country all over. I early realised that a long campaign would be necessary in order to obtain the acceptance of the main principle. The first appearance in public of the scheme was in the "Star" of Johannesburg, of the 31st January, 1918. This was followed by a paper read before the South African Association for the Advancement of Science, at the Johannesburg meeting in 1918. In the discussion that ensued, there was manifested almost a resentment that such a big scheme should be mooted, when there were so many little affairs for people to take an interest in. The ordinary mind—and scientists are not excepted—cannot think in continents, and is easily put off with temporary expedients as long as there are facts that can be readily grasped. For instance: A dam will cost, say, £10,000; will irrigate, say, 1,000 acres; therefore a simple calculation will enable one to see whether the scheme will pay. Once the calculation is made, it is no use reopening the subject; "Let the project have its chance," is the usual attitude of most people, and if one points out that there are factors, such as evaporation, brak, and silt, which may ruin the proposition, the tendency is to keep away from such evil prophecies. Then, in imagination, after an irrigation project has been started, and a few

morgen of land have been made to blossom as a rose, the mind sees the process indefinitely repeated till the whole country is redeemed. Some illustrious person asserted that a certain method, if employed in baling out the silt in the Bloemfontein Reservoirs, would end all their troubles; the Town Engineer calculated the time required to take out the silt on this method, and the result was 270,000 days! In the same way people forget the immense size of South Africa; the time required to restore the country to habitableness, by the conservation of flood-waters in the ordinary way, would be well over 270,000 days, and in the process the country would be rendered bankrupt with the expense. The description of my Ovamboland trip was published in the Johannesburg "Mining Journal," and through the courtesy of the Editor, Mr. Clem. Webb, I am able to reproduce much of the material in the present work.

The Kalahari Scheme deals with an area far away from the haunts of men; the benefits are not like when one leads actual water on to a definite piece of land, and the mind of most people boggles at the proposition. "It is only a theory, which may or may not be true," is the usual verdict. To one who has spent his life in the field in South Africa, evaporation, head-stream erosion, and such agencies, with which I deal in the following pages, are actualities enough, and the arguments that I have brought to bear on the subject and the results to be expected from the Kalahari Scheme are not in any way theoretical, or based on unproved facts. They are denied resolutely in some quarters, and I can only appeal to the facts themselves as I have marshalled them in this book, to let them tell their own story.

I show in the following pages South Africa as it is. A high block of land with steep borders; from all sides the water that accumulates in the interior is pouring away through innumerable gaps in the hedge of the encircling coastal mountains. The central districts, too far from the sea to benefit by the moisture blown inland from the ocean, are becoming drained. We must turn off the taps. The evaporation is three times the rainfall, which means that the air is drawing on the soil to supply its own humidity, and is carrying away the dampness of the soil, without which the plants cannot live, to fertilise other regions. On all hands South Africa is being wrung dry. The central lakes that used to exist, and of which the last dried up in 1820, are no longer there to supply the moisture for the air in the central districts, so that sea-borne moisture, which, if reinforced with a little from the air over the land, would result in rain, finds the air hot and dry, and the moisture is blown away and is lost to us. I show South Africa before 1820, when Lichten-

stein, Barrow and Le Vaillant shot hippopotamus in the Karroo rivers and hunted rhinoceros, eland and hartebeest in the forests along the banks, where there is now nothing but prickly pear. I show the progressive intensity of the droughts; the centre of the land becoming depopulated, and its inhabitants crowding along the coast, where the rainfall allows them to raise enough food to feed their families. I show the land full of starving men and animals as the result of the droughts.

I then bring in the Kalahari Scheme. The old lake floors are plotted and shown on all maps, and the peculiar courses of the rivers indicate the manner in which the Kalahari lakes have been drained by the Zambesi. The means for stopping up the gaps are there; the channels for filling the reservoirs, though choked up, are in existence, and the natural depressions only wait for the water, to function once more as rain-distributors for South Africa. In the west, desert conditions are creeping into the area of the head-streams of the Zambesi, Chobe, Okavango, Cunene and Congo Rivers. The Ovamboland Plain, a natural swamp, like the Bahr-el-Ghazal on the Nile, that used to supply these great rivers by the evaporation from it, is becoming a waterless waste, and our big rivers, on which the fertility of half the continent of Africa depends, are in danger of extinction. Events are happening so rapidly, that the danger is affecting us even now; since Livingstone discovered the Chinde mouth of the Zambesi the river has shrunk, so that it is of no more use for traffic.

When the gaps are blocked up and the old Kalahari lakes are once more there to supply the air of South Africa with moisture, the old central river of the Kalahari will once more flow. All down the course from Ngami to the Orange River, below the Falls, settlements will arise and agriculture, of the name nature and on the same scale as that in Egypt, will spring up. Yet it will be a better Egypt that will result from the occupation of this wilderness, for there will not be desert around. The Kalahari to-day is covered with bush and grass; when the lakes and rivers are reconstituted, the vegetation will be that of the Soudan; rich pasturage and forest. Only the more important crops will need irrigation, and harvest will not be followed by the clean-sweep of every sign of vegetation. Away from the central river there will be stock farms, contributing to the wealth of the country, and every acre of the land will become habitable. So with the rest of South Africa. The irrigation projects at present in hand or in actual operation, provide narrow strips of land along the rivers, fit for occupation, leaving the vast stretches around unaffected, for the areas irrigated are too small to make any impression on the country as a whole. These represent

1/700th of the parched land; the Kalahari Scheme, with its water-surfaces and irrigated lands, represents 1/10th. Whereas on the irrigation schemes, only men with considerable capital can be expected to benefit, on the Kalahari project, everyone in South Africa, whether he wants it or no, will receive the additional rain, will see his land rendered more fertile, and all his difficulties from drought, famine and pestilence disappear.

This book is published with a view to familiarising people with the Kalahari Problem. I have set out the arguments as concisely as I could. I have referred in the text to the criticisms that have been made with reference to it, but so far nothing has appeared which invalidates in any way the central proposition. A great scheme like this requires an immense amount of preparation, and I did not anticipate its acceptance at once; its adoption must come in the end, and everyone who discusses and studies the question will hasten the time when the efforts to bring about this salvation of South Africa will bear fruition.

MAP I. The Proposed Irrigation Schemes in the Kalahari, by which South Africa, the great Thirstland, may be redeemed.

PART I.

EVIDENCE OF THE DRYING UP OF SOUTH AFRICA.

Historical Record.—Wherever one travels in South Africa, and at the outspan talks with the owner of the farm, one hears tales of the country having been much better supplied with rain. "Fifty years ago the river used to run ten months in the year; the grass grew over a large portion of the farm." "Droughts?" "Yes, there used to be bad droughts, but after the droughts one could reckon on having a succession of good years; nowadays, the droughts follow droughts, and the land has no opportunity of recovering." Such are the tales; is there any truth in them, or are they just the ordinary stories of old men who think that the world went better in the days when they were young? If one studies the literature on South Africa, say, from the time of George Thompson, 1827, to that of Gordon Cumming, 1850, one is impressed with the similarity of the conditions between then and now; the same droughts, the same floods in the rivers, bringing down masses of mud instead of water, the same failure of harvests, only the distress was not so acute as nowadays. From this evidence, many people deny that South Africa is drying up, and maintain that we are just going through an ordinary cycle of dry years, to be followed presently by a cycle of good years, when all our losses will be made good and our troubles

forgotten. I will show in the sequel that the droughts are becoming worse and worse every year, that people are even now becoming squeezed out of the central districts and are taking refuge on the coast, where conditions of life are still normal, and that the time is not far distant when the Karroo will become as desert as the Sahara, where exactly the same thing happened a thousand years ago as is actually happening before our eyes to-day in South Africa. I shall show that the critical period for South Africa was 1820, when the Ngami Lakes dried up, and the source of inland moisture, the great surfaces of water that had existed up till then, disappeared, the waters being drained away by the Zambesi, to the sea.

If we, however, turn to the earlier travellers, we find that though the western Karroo had already advanced far towards its present condition, the eastern Karroo was very different. The most descriptive of the travellers, Le Vaillant, made two journeys in Africa, in 1780-82, and again in 1783-85, and if he was unsupported one would be inclined to doubt his word, but his facts are substantiated by both John Barrow, who travelled in 1797, and by H. Lichtenstein, who travelled in 1803-06. I am indebted to Mr. J. Hewitt for the following extracts from the works of these authors. John Barrow crossed the Kowie River, south of Grahamstown, in 1797, and describes the great herds of elephants that roamed the forested kloofs near the Kariega River, whilst lions, leopards, hyaenas and other beasts of prey abounded in this wild part of the country. On the Zuurveld, the mountain ridge that runs east from Willowmore, past Grahamstown to the Gulana River in Peddie, he noticed steenbuck, bushbuck, reedbuck, oribi, and records having shot several hartebeeste. At the Great Fish River he saw a vast number of hippopotami, and the neighbouring forest was frequented by rhinoceros. Le Vaillant passed the Great Fish River, near Cookhouse, in 1781; he records having met with koodoo, buffalo, lion, hartebeeste, wildebeest, springbuck and ostrich, while in the river hippopotami were abundant. Lichtenstein's route took his through Assegai Bush, in the Albany district, New Year's Drift, and Commadagga, and afterwards

along the south side of the Great Fish River to Hermanus Kraal. Near Dassie Klip (Deur ?) he saw a great number of quaggas, now extinct (unless the report be true, that there is a herd of them in the Kaokoveld, on the north of South-West Africa). Le Vaillant remarks that a huntsman in these parts must be equally armed against an elephant or a rhinoceros as against smaller game; he seldom shoots with a ball of less than two ounces. The aridity of the Great Fish River in these parts, even seen from the train, is now only relieved by the prickly pear, which seems to thrive on the soil which the indigenous plants have abandoned in despair, and elephants, rhinoceros and hippopotami could not exist in the country in its present condition. This same traveller records taking a short hunting trip towards the mouth of the Great Fish River, when they shot five hippopotami, eight rhinoceros, nine hartebeeste, and smaller game that they did not count; the booty, in the shape of the fat of the hippopotami, rhinoceros skins, and dried meat, was sufficient to fill three large waggons. He saw further, a large troop of quaggas, rhinoceros and hartebeeste, between Carlisle Bridge and Fort Brown on the Fish River. Hippopotamus are recorded up as far as Rosmead, eighty years ago; this is a typically bare Karroo locality, yet when the fathers of the present owners of the farms there first occupied the land, the oxen, when they lay down, were hidden in the long grass. In those days, the assemblage of animals that roamed the eastern Karroo must have resembled that now found in East Africa, and the whole appearance of the fauna and flora of South Africa was distinctly more tropical than it is to-day.

The large game mentioned above are not like some animals, for instance the tiger that is found in the tropical jungles of Bengal and the frozen plains of the Amur; they are sensitive to both climate and suitable grazing and water. A last remnant of the fauna still exists in the Addo elephants, but these have lingered on under exceptional conditions, and to-day those conditions have become so altered that it is a mercy to kill them off. A little vley was kept for them near Mimosa Station, at which they drank every other night, but that has been dry now for many months in the year, and

they have had to find water in the farm dams; when these failed they even tried to suck up water from a well right alongside the farm-house on Mimosa.

I shall show later on that the drying up of the country was consequent on the draining of the Ngami lakes. The Greater Ngami was drained first, probably 250 years ago or thereabouts. No one was up in those parts at that time, though, curiously enough, the missionaries at Zumbo maintained that in their time, shortly after the Portuguese occupation at the commencement of the sixteenth century, the Zambesi had not breached the Falls, but began at the base of them. Livingstone dismisses the story as fable, and doubts whether any Portuguese had enough energy to explore so high up. There was a time, however, when all the water from the Barotse Valley was impounded in the Ngami and Makarikari depressions; then the Zambesi breached the Falls and let out the waters of the Greater Ngami lake, leaving the Makarikari still with the waters of the Chobe and Okavango Rivers. I date the drying up of the Karroo from the draining of the Greater Ngami, and the drying up of the eastern portion only after the Makarikari ceased to be a lake in 1820. At any rate the configuration of the Karroo round Beaufort West is precisely the same as that round Cradock, only the draining and drying-up process is more complete. The rivers are of the same type, and although I cannot appeal to actual descriptions of the western Karroo, the persistence of the nomenclature of these parts points to the existence of the larger quadrupeds, lions, hippopotami, and so forth, exactly as in the eastern portion. The Gamka River is certainly the Lion River, and was so named by the Bushmen from the number of lions along the banks, in the same way that they have named the Gamka River in Ovamboland. Zeekoegat, on the Traka River, north-east of Prince Albert, is named from a deep hollow in the river that holds water after the flood-water has passed; these hollows are named zeekoegats wherever they are found, and those who maintain that the Karroo was always dry maintain that it is merely an expression used by the Dutch who have seen real hippopotamus hollows in the north, and applied by them to a

similar physical feature at their homes. To say that these Dutch were not such extensive travellers as to account for the universal application of the term to these pools, and that they have acquired the name from the early Bushman servants of the original settlers, is merely to state a belief and cannot rank as proof, however much we may hold this to be the true explanation. When we dig, however, in the banks of these dry rivers, we find almost everywhere the bones of the larger game, including hippopotamus. I have been shown the bones from practically all over the Gouph, west of Beaufort West and round Prince Albert; wherever a weir is built these bones turn up, sometimes the remains of hippopotamus, rhinoceros, eland, or quagga, but always indicating that tropical animals, requiring vast amounts of food, existed along these rivers, where now only small stock can live.

For scientific proof of the earlier state of the country, these mouldering fragments should be preserved; usually they are flung aside, but in the Albany Museum, Grahamstown, there is a collection of these, including a fine crocodile skull from the Uitenhage vley, besides a large number of rhinoceros, hippopotamus and eland skulls from the sides of rivers in the Albany district. It is a historical fact, also, that immense quantities of large game roamed the plains of the Karroo, in density equal to the great herds that exist in the Game Reserve in British East Africa, or in the Game Reserve in Ovamboland. I myself have never seen more than some 500 zebras in one herd, together with lesser numbers of wildebeeste and a few gemsbok and springbuck, but the Game Ranger, the late Mr. Breijer, counted 7,000 in one clump; the zebras ran past him for an hour in a stream half a mile wide, and his estimate was confirmed by the Magistrate of Tsumeb, who was with him at the time. At Namutoni, on the Etosha Pan, Mr. Breijer estimated that six zebras were killed by lions every night; my wanderings round the place, when I constantly came across recently gnawed bones, made me acknowledge the reasonableness of the estimate, though I never had the good fortune to actually see a lion. The Heikum Bushmen eat lions, and Anders-

son says that the flesh is very palateable and juicy, not unlike veal, and very white. The great hunters like Oswell and Gordon Cumming describe similar herds round Cradock and Colesberg. Prince Albert, when he visited the country in 1860, was given a royal shoot at Bain's Vley, just outside Bloemfontein, when a bag of 6,000 head of game, large and small, fell to the guns of the party in one day. It is incredible that the country could have supported such vast quantities of animals unless the climate and vegetation was very different from what it is to-day.

Beer Vley, north of Willowmore, a desolate, dry waste, is described by Barrow in 1797 "as a plain of several miles in diameter, stretching along the feet of the Black Mountains, and seemed to be the reservoir of a number of periodical rivers, whose sources are in the Nieuwveld, Winterberg and Camdeboo. One of these running at this time with a considerable current was as salt as brine. Another river, with little current, called the Karooka, joined the salt river at the head of the valley, the waters of which were perfectly fresh, but combined with earthy matter. The surface of the valley was entirely covered with two or three species of coarse rushy grasses; and all the swamps and springs were buried in large clumps of *Arundo phragmites*, or common reed. The streams that fell into the valley were finely skirted with tall mimosas, which in their confluence, spread out into a forest. Such a delightful spot in the midst of the barren desert, afforded shelter, food and water to a vast variety of game, three species of which we had not previously observed; these were the springbok, gemsbok and koodoo." This was an oasis left of former luxuriant times, and we must go to the swamps of the Okavango now to find similar conditions.

The question why the west dried up earlier than the east is explained further on, but it may be here briefly referred to. The ocean currents on the west coast come from the Antarctic and are cold, and therefore do not provide so much moisture to the air as the warmer currents on the east coast, which come from the equator, hence, when the first of the

Ngami Lakes disappeared, the west was the part to be most affected; then when the second of the great sheets of water dried up, the east became also affected.

Was man, perhaps, responsible for the desiccation of the Karroo? In the case of Beer Vley, for instance, was over-stocking the cause, and did cattle tramp out the vley and thus allow the water to escape? This was certainly what happened, but the prime cause which drove the cattle to collect in the vley and destroy it, was the droughts that drove them from the open veld. We shall see this illustrated again and again in the course of this book; all the dongas, veld erosion, silting of dams and destruction generally of the natural surface of the land, can be traced to over-stocking and concentration of animals round water-holes and dams. If, however, the surface of the ground were properly protected by plants growing under normal conditions, then all the over-stocking possible could not produce the effects so apparent all over the Union of South Africa. Do away with droughts and the destruction of the veld will cease; nothing of the kind goes on in England, or even in Natal, where the nearness to the warm Indian Ocean secures to it a plentiful rainfall.

Turning to the Transvaal, there is a valley to the south of Johannesburg, the Klip River Valley, that leads into the Vaal River at Vereeniging. The later history of this once fertile valley is told in two Parliamentary Reports, for the farmers have complained that the excessive pumping from boreholes to supply Johannesburg with water has caused their springs to dry up, and they can no longer irrigate. It is, however, with the contrast between what the Klip River was like 80 years ago and what it is like now, that we are concerned. Driving from Johannesburg to Vereeniging one passes over monotonous grass veld, too dry to grow crops without irrigation, and worth £15 a morgen, in spite of its nearness to Johannesburg; yet there are men of unimpeachable veracity who tell one that their fathers shot hippopotamus in the vleys, such as that at Zwartkoppies, one of the Rand Water Board pumping stations, and the whole

valley was full of water. The present rainfall of the area is some 30 inches, but the evaporation is 90 inches a year. No further explanation is necessary for the disappearance of the former fertility of the valley. When the great lakes in the Ngami area supplied the High Veld with moisture, the evaporation must have measured only a fraction of 90 inches; what water went into the soil remained there, and was not wrung out again by the intense dryness of the atmosphere. The effect may be illustrated by what happens in Kimberley; unless one keeps bowls of water in the rooms, the furniture cracks in the summer from the dry heat. The Ngami Lakes played the part of the bowls of water, and as long as they were there the veld remained normal; directly they dried up, the Klip River Valley and the rest of South Africa began to "crack," or, in other words, became drought-stricken.

Rainfall Statistics.—One of the most fatal mistakes that people make in discussing the variation of climate, is to take the rainfall statistics without qualification. In the first place a drought year may have to its credit actually a higher rainfall than a normal year, because in one or two heavy floods more rain may fall in a few hours than in as many months in other years. It is the distribution of the rain that counts. Two months' scorching drought followed by ten inches of rain, as we often get it in the eastern Karroo, is worse than nine inches spread over three months, and should be counted as a drought year. There are other factors, as we shall see, that also make simple rainfall records most misleading. Mr. G. W. van Zyn has gone to the trouble of analysing the rainfall statistics, month by month, for the eastern Karroo. He was fortunate in having the rainfall for Graaff-Reinet from 1874, which were taken by Mr. S. Rubridge, of Wellwood. Combining these with those from Colesberg and other centres in the eastern and north-eastern Karroo, we have the following figures. I have divided them into two lots of 22 years each, so as to allow of easy comparison, and to show how the droughts are becoming progressively more frequent, and the good years fading almost into past history.

	Rainy Years; over 17 inches, evenly distributed.	Normal Years; over 13.5, evenly distributed.	Lesser droughts; over two months' summer drought.	Bad droughts; over four months' summer drought.
	1875	1878	1879	1876
	1880	1885	1881	1877
	1886	1887	1882	1884
	1889	1888	1883	
	1890	1891	1895	
	1893	1892		
		1894		
		1896		
TOTAL	6	8	5	3
	1906	1900	1897	1902
	1917	1905	1898	1904
		1909	1899	1907
		1916	1901	1912
			1903	1914
			1908	1918
			1910	
			1911	
			1913	
			1915	
TOTAL	2	4	10	6

From this table one will notice that the droughts have just doubled in the last 22 years, as compared with the previous 22 years; the normal years have been reduced by half, and there are only two good years, as compared with six; 1874 was a very good year, and 1919 a very bad drought, so if we take 23 years the comparison is still worse. Combining the lesser and the greater droughts, we have:—

1874-1896:	7 good years;	8 normal years;	8 droughts.
1897-1919:	2 ,, ,,	4 ,, ,,	17 ,,

It is not as if this table stood alone; it was corroborated in a most striking way by a table of the flow of water in the Vaal River at Vereeniging, published by Mr. A. Karlson, at one time Hydrographical Engineer in the Irrigation Department, though the records do not range over such a length of time. The table, however, reveals a most serious state of affairs. No cycle of dry and wet years can explain away the obvious conclusions that an ordinary person must draw from these data. The longest cycle is one of 35 years, with a maximum rainfall in 1916; well, 1917 was a good year, but 1918 was a bad drought year, and 1919, so far, is the worst drought we have had for 50 years. Plain facts show that manoeuvring with long or short cycles of weather does not pan out. The records for the coastal areas show considerable differences, for there one has the sea as a constant stand-by; the table of Mr. Van Zyl reflects faithfully what is going on in the interior of the continent, and even this will react on the coast belt in time, restricting the favourable areas, and giving rise to hot, blasting winds, like the Sirocco or Harmattan of North Africa. The cost to South Africa of the last drought, 1919, estimated on the number of sheep and cattle dead of hunger and thirst, and crops that failed, is £11,000,000; and this has been at a time when foodstuffs were peculiarly valuable.

In North Africa we have a description of Tunis by Herodotus, about 450 B.C., 2,370 years ago; he describes a great lake, Palus Tritonis, into which fell a great river, and on the banks of which lived natives very much the same as

the present-day Ovambos. The lake has silted up, and now forms the Shotts Melghir and Jerid; the river, Wady Igharghar, can only be traced as a dry bed in among the sand dunes. Tripoli had three flourishing cities along the sea shore, sending merchandise from the interior all over the Mediterranean; one of the cities still remains, still dealing with the same trade, but the way is now very far to the Soudan, and the volume very much restricted. As a matter of fact, the whole sea-board of North Africa is littered with the ruins of vast cities, Phoenician, Greek and Roman, and the "emporiums" supplied the civilised world with grain and produce from the well-watered lands in the interior, much as our coast ports do now. What has happened to North Africa is happening to our own South Africa, with this difference, that the cause of the drying up has been discovered, and is of such a nature that engineering skill can still tackle it and make our country what it was like 300 years ago.

Census Returns.—I am indebted to Professor W. M. Macmillan for an analysis of the census returns of the Union of South Africa, published in a pamphlet "The South African Agrarian Problem, and its Historical Development, Johannesburg, 1919. Of the White population of the Union, nearly one-twentieth are in permanent absolute poverty, "*Dood arme,*" many of them demoralised beyond redemption; in addition, considerably more than another twentieth are in jeopardy of being dragged down to the level of those submerged. In the map published in the pamphlet, the most remarkable feature is that it presents an almost solid stretch of country, right across the centre of the Union, in which there has been an absolute decrease of population, while most of the coastal districts, the north and also the most remote and undeveloped north-west show a decided increase. "Two important factors help to explain why the central areas should have suffered something of a check, namely, a very severe drought and the slump in ostrich feather prices. It has been suggested that the 1911 Census was inaccurate; but inaccuracies cannot explain away the general impression. When there is no reason to suppose the decreased areas to suffer either from a low birth-rate or an excessive death-

rate, an absolute decrease in what are for the most part sparsely populated districts is not to be taken lightly, for in 1911 the density to the square mile exceeded 20 in one case only, that of Oudtshoorn; in several others the density was only 3 per square mile, or even less.

"In Karroo and semi-Karroo districts the only ones showing only a very small decrease, 2 per cent. and under, or a small gain, would seem to be the scenes of irrigation schemes on the Fish and Sundays River, or along the Orange River. In a different case there is the Division of Herbert, increase 26.88 per cent., accounted for by the possibly forlorn hope of the River Diggings. There are two other increases, De Aar and the village, though not the district, of Beaufort West, two considerable railway camps. Apart from the Karroo, there is the case of districts like Albany, due probably to the ostrich slump, but also to drought, while the virtual stagnation of Riversdale and Swellendam, in what would seem to be a more favourably situated area, may be due to the fact that their rainfall is not as good as that of their neighbours, partly also to ostriches, and perhaps not least, to their very unfavourable railway service.

"As to areas that show an increase, the towns in some cases, like Benoni, have grown considerably, but in the case of the Witwatersrand as a whole, an increase of over 10 per cent. is in no way portentous. It is, I think, noticeable that the increase in some rural districts is proportionately even greater. The cases of the northern Free State districts are accounted for in part by their better and more reliable rainfall, by the great development of mealie-growing and of dairying, and more generally by their proximity to the best market in the Union. The High Veld of the Transvaal had perhaps earlier reached a relatively high stage of development, and there was less opportunity for rapid growth, while the Low Veld and even some of the remote districts of Bechuanaland and of the North-West Cape (some of them, like Zoutpansberg, with an increase of 73 per cent., apparently very great) are significant chiefly as indicating the advance of pioneers—and even with their 72 per cent. increases, the total white population is trifling. They do,

however, seem to indicate that there are still pioneers, in some cases possibly of the type of the old-time Trekkers. It seems to be the case that the North-West farmer is still the Trek Boer, and treks still further to the north, just as from the Midlands economic pressure drives families to the coast. But to my mind the most significant increase is in the areas of the south coast of the Cape—George and Humansdorp, with over 20 per cent.; even Knysna, with no railways and in some sense already overcrowded (density in 1911, in spite of forest and mountains, 13.1 per square mile) increases 6.9 per cent., and Uniondale 8 per cent., when half the district is Karroo, and probably shares in the decrease. Taking all the facts into consideration, I think the Census confirms the view that the drift of population is not by any means all townwards. Allowing also for the badness of the drought of 1914, droughts not being unprecedented in that area, and recognising, of course, that the Karroo includes different types, not all of which need be equally affected, there seems to be some indication that, on present terms and under present conditions, the Karroo generally, but not the coast, has reached something like the limit of its capacity to support its population."

A most significant statement occurs in a communication by Dr. Henderson Ruthven, in the "S.A. Medical Record." On a medical inspection of an elementary school in a Karroo village, of the 200 odd children, 60 per cent. were in some way defective, many of them simply undernourished.

No amount of denial can detract from the value of these facts. Irrigation will help to a microscopic degree; building of railways will provide work and wages; good years will enable a few favoured individuals to get rid of their difficulties, but the fact stands clear and incontrovertible, that the centre of the country is becoming more and more impossible for existence, and every drought squeezes out more and more of the population into hopeless poverty. According to Mr. Van Heerden, and lately to Major Naudé, there were in 1916 and 1917 some 10,409 heads of families, 39,021 individuals in all, living in absolute poverty, and 16,605 heads of families, 67,497 in all, in something a little

less than absolute poverty—a total for the Union of South Africa of 106,518, or something over 8 per cent. of the total population. These are what are called Poor Whites.

There is the argument: "Why try and do anything for the Karroo, as it is such a dismal country, and becoming so manifestly worse?" There is the old Boer argument that the Deity, having made the Karroo on top of the ground such a barren waste, must, in fairness, have buried great treasures underground, and many a wily prospector has obtained handsome tribute from the unsophisticated Dutchman by working this idea. The answer is that Karroo conditions are spreading; even in Natal, with the warm easterly winds bringing the rains from the Indian Ocean, this creeping on of desert conditions is noticeable, and unless something is done, even the coast regions will become uninhabitable.

Evaporation.—The ordinary evaporation from the surface of a sheet of water depends on the humidity of the air and the amount of wind that stirs up the lower layers of the atmosphere; there are also two other ways in which the air is reinforced with moisture, from evaporation from the exposed surface of the soil, and by transpiration from the leaves of plants.

The humidity of the air is measured by readings of the wet and dry bulb thermometers; the difference has to be corrected by applying certain "factors," which have been determined accurately from experience. Then, if the wet bulb thermometer reads, say, 50, and the dry bulb 60, and the factor is 2, we multiply the difference by 2 and obtain the result, that, with a temperature of 60 the "dew point" is 40, or in other words, the air would have to be cooled 20 degrees before rain would fall. If the wet bulb thermometer reads 60 and the dry bulb 60, then the air would be saturated with moisture, and rain would fall with the slightest lowering of the barometer. In the latter case the air would be said to have 100 per cent. moisture, and it could not take up any more; in the former case the air would have very much less than 100 per cent., and would absorb moisture from any free surface of water. Ordinarily the air contains 70-80 per cent.

moisture in South Africa, but in the dry parts of the Karroo, in the summer, the percentage falls to 25 per cent. There is an average of 65 per cent. at Cradock and Graaff-Reinet, 58 per cent. Bloemfontein, and 50 per cent. Kimberley. With these low percentages, all moisture in the soil and plants is wrung out of them, and the vegetation is withered, the land parched, and conditions are very trying for all living beings, men and animals. Evaporation under such circumstances is rapid.

Wind also helps evaporation. Water-vapour dissolves in the air much in the same way that sugar dissolves in the fluid in a cup of tea; as long as the tea is not stirred, the sugar will not readily "diffuse"; so with the water-vapour. It is a provision of Nature, to preserve water in dry regions, that unless the air is stirred by winds, the layer of saturated air just above the surface of the water protects the water, in that it itself cannot take up any further supply, and it yields what it holds slowly to the dryer air above. We have two striking instances. On the Gatun Lake, on the Panama Canal, in a hot, steamy atmosphere, because of the high and constant winds, the evaporation is 90 inches a year; at Kimberley, where the air is so dry that readings of 25 per cent. moisture are obtained, because of lack of constant winds, the evaporation is only 60 inches. In Grahamstown, with the high percentage of windy days, the readings run over 90 inches, about the same as at Johannesburg.

With evaporation one must compare the rainfall; at Grahamstown and Johannesburg the rainfall is something under 30 inches, so that the rainfall is one-third of the evaporation; Kimberly, rainfall something under 20 inches, evaporation 60, again about one-third. In England, on the south-east coast, rainfall 30 inches, evaporation 15 inches, that is, rainfall twice the evaporation. Under English conditions the vegetation can thrive without actual rain, because the moisture in the ground is not wrung out again as soon as it has entered it. Under South African conditions the plants have a hard struggle for existence, and under the circumstances two types of vegetation have been evolved to meet the conditions:—I. The plants have adopted devices

for conserving moisture, in that they have small leaves and woody stems, or fleshy leaves with few pores for transpiration, or they have fleshy stems with leaves small or practically absent, or the stems and leaves are covered with white, hairy down; or, again, they have underground bulbs, and only throw up surface structures when it rains. This is the *Karroo type* of vegetation, marked especially by the predominance of the Mesembryanthemum family of plants; as a rule, there is no soil above ground, the shaly rock is exposed on the surface, and the plant roots have made their own soil in the cracks into which they have penetrated. II. *Kalahari type.* Here the ground is covered with soil or sand; when it rains, grass ("Bushman grass," *Aristida brevifolia*) springs up quickly and withers, covering the surface with seed, for use in the next rains. I have seen withered grass three years old in the Kalahari, alongside grass two years, where the game, in this case elands, had eaten down the former season's grass, and again an area covered with last year's growth. In these cases, the ground lies fallow after the grass has grown, and no transpiration of moisture or any activity in the soil goes on after the grass has finished growing. In Basutoland, where the same type occurs, in the droughts, all vestige of vegetation disappears, even the withered grass is greedily eaten by the famishing cattle, and the whole country is swept as clear as the surface of a high road. The carrying of seeds of grass is quite extraordinary. In the Namib, the desert of shifting sand dunes, on the coast of the South-West Province, after a rain in 1917, grass sprang up and large quantities of hay were mown in places where nothing had grown since it had been known to white men. In another case, in Somerset East, after a drought, a denuded patch suddenly became overgrown with a peculiar kind of grass that had never been known before in the district, and the nearest country where it grew was 30 miles to the north.

In the Karroo, after a rain, there is a growth of grass and plants that ordinarily thrive in better watered parts. This is known to the Dutch as "opslag." Ordinarily, the hot, scorching winds cut down this growth before it has attained any size or strength, but it does happen, now and

again, as in the Cradock district in 1906, that the rains are sufficiently continuous to allow it to spread, and a most extraordinary result follows: the bare hills are covered to their tops with green grass, and one might imagine that the kopjes were somewhere in Europe. One hill in Cradock, especially, reminded me in this condition of Arthur's Seat, Edinburgh. I have only seen this phenomenon once in twenty-five years. In the Kalahari type of country, the soil is not suited to the development of Karroo bushes, which require firm rock to hold the roots, and the grass simply withers; if the droughts last long enough, the ground becomes simply shifting sand. If, on the other hand, drought conditions supervene in the grassy coastal regions, where there is suitable soil, then the Karroo conditions creep in with the appropriate bushes.

Most botanists maintain that the Karroo bushes are of such a peculiar type, that they must have taken untold ages to acquire their adaptive modifications. I should like to leave it at that, as the point is one for argument, and does not affect the facts that I have brought forward to prove the former condition of the Karroo, indeed the great rivers, with the fish swarming in the pools after the rivers have come down, is enough for any unbiassed mind to be satisfied with, let alone the historical facts about the hippopotamus living in them in the time of Lichtenstein, Le Vaillant, and Barrow. Even stronger proof is afforded by water-wheels and mills on the tributaries of the Fish River, in the Cradock district, where there has not been enough water to work them for two generations. There are geological considerations, however, that the botanists have not appreciated, and I will deal with the matter here, using South America as an example, where there is a gap in our own story of the rocks.

The occurrence of xerophytic plants depends on the climate. The main factor is absence of moisture in the atmosphere, but an additional factor is the intense heat during the day and corresponding cold at night. Two regions have such a climate—the arid regions and the mountain regions. The first is arid because there is no source of moisture at hand, the air is so dry that the sun's rays strike directly downwards, without the screen of vapour that shelters the

earth in more favourable localities. In the mountains, the same physical features are reproduced; the air is so rarefied that it cannot hold moisture, and the little that the plants obtain in the way of mists has to be tightly held against the scorching heat during the day, for the thin atmosphere, here also, does not screen the ground from the direct rays of the sun.

At the present day there are no mountains in South Africa high enough to show the true Alpine flora. It is true, in the mountains of the Western Province many plants that grow lower down, on the summits take on Alpine features, such as recumbent attitude and stunted growth, with large root growth, but then these mountains are sour veld, whereas the Karroo is sweet. In the east, there are mountains of basalt, with sweet veld, rising in the Mont aux Sources to 12,000 feet. On the sea-ward side there are the denuded chimneys of the volcanoes, and it is very sure that at no very distant date, these mountains rose to 20,000 feet. There was, in fact, a range of volcanic peaks, in all respects similar to the Andes, with its Chimborazo, Cotapaxi, Illimani, and Sorata. If one needs to find a place where the Karroo plants developed when the whole of the country was well watered, there in these hills is the required area, with all the necessary physical conditions; then, when the country dried up, the plants came down, their seeds wafted by the winds. We know that the Karroo plants do now follow the retreating grass veld after a succession of droughts, just as the grass veld will invade the Karroo veld and kill out the bushes in rainy years. It does not seem, therefore, that the argument that the Karroo must have been always dry because plants adapted to dry conditions live there at the present time, has any weight. In South America the desert flora is characterised by the Cactus family; the Cactus does grow in the higher Andes (Sorata, Sir Martin Conway), but I cannot find out whether the family is sufficiently represented to argue from it that the higher Andes was the original home. One is inclined to doubt that on the restricted area of the mountain slopes, species can evolve which are represented by millions of individuals spread over the level square miles of the desert, but a single small clump of peculiar plants that have become

adapted to special conditions may give rise to a world-wide species, should conditions become favourable. We have in South Africa the example of the Rhenoster Bush, that is said to have sprung from a few plants brought to Simon's Town; or there is the better-known example of the prickly pear, that was propagated from a couple of leaves introduced into Australia by one of the early explorers, and is now spread all over the continent.

I have said enough to show that evaporation plays a more important part in the economy of a country, in the lives of the men and animals, and in the growth of the crops and pasturage, than the rainfall. Unfortunately everyone can buy and use a rain gauge, but to handle an evaporation tank requires a considerable amount of skill and precaution, setting aside the clumsiness and expense of the apparatus. Ordinarily, a tank of convenient size, about 18 inches deep, is used, and the loss from the surface is measured daily, allowance being made for any rain that may have fallen. Another device that can be bought from the instrument-makers, is an evaporimeter. This is an instrument consisting of a stretched sheet of linen, about six inches by four, which is kept wet by a lamp-wick attached to it, and resting in a flask of water. The linen sheet is exposed to the air, and the water is evaporated from it; more water is drawn up from the flask by capillary attraction by the lamp-wick. The graduations on the flask allow one to read off directly the amount of water that has disappeared by evaporation, in terms of a standard square foot, so that the unit for the rain gauge and the evaporimeter is the same. The instrument is subject to many inaccuracies, but it has been compared with the evaporation tank at Kimberley, so that corrections may be introduced which should allow one to obtain tolerably good estimates.

I am indebted to Mr. W. Ingham for the following figures for the evaporation at Johannesburg; the records are from the Union Observatory, situated in the centre of the suburbs, and the progressive decline of the yearly evaporation measures the effect of the increasing watering of gardens, cultivation, tree-plantation, and so forth. On a small scale it accurately illustrates what will happen to South Africa as

a whole when the Kalahari is irrigated, and forms a distributing centre for moisture.

Evaporation Records taken at the Union Observatory, Johannesburg.

	Inches.	Average 3 years.
1904	92.3	
1905	84.7	82.3
1906	70.1	
1907	76.7	
1908	66.6	70.9
1909	69.6	
1910	65.0	
1911	71.9	68.6
1912	68.9	
1913	69.7	
1914	61.0	62.1
1915	55.6	
1916	61.8	
1917	54.0	55.8
1918	51.6	

It is to be noted that evaporation outside Johannesburg, along the reef, remains about 90 inches.

South Africa has become Colder.—It has been a matter of surprise that the fauna of the Eastern Province should have been the same as that now found in East Africa, where the temperature is so much higher. There is every evidence that formerly South Africa did enjoy a higher average temperature than it does to-day. As regards the fossil evidence, the shells found in the raised beaches near Port Elizabeth are distinctly tropical. I have collected largely in these deposits, together with my students, when on geological expeditions, and the fossils have been described by Mr. Bullen Newton, of the British Museum; the date of the raised beaches, is,

however, Mio-Pliocene, and therefore they do not concern us here, except in so far as they prove tropical conditions preceding the present epoch. The later deposits are found in the drowned valleys of the rivers flowing into the Indian Ocean, and I have also collected from the Knysna rivers—the Pisang, Bitou, and Keurbooms Rivers—the Zwartkops at Port Elizabeth, and the Bathurst River, the Kowie. The outstanding fossil of these Pleistocene deposits is a great *Panopaea natalensis*, which used to be found living in the Durban lagoon, but which is apparently now extinct; it is a typical warm water shell. Elephants still roam the Knysna and Addo Bush, but these great beasts have always lagged behind the other animals when migration become the order of the day, due to change of climate: witness the mammoths in the frozen tundras of Siberia. Hannibal, too, took elephants across the snow passes of the Alps, and we know that they live quite well in the Zoological Gardens of north Europe and America. If, however, we examine the whole of the animals that are found in the recent deposits along the river banks, the assemblage is distinctly tropical; we find crocodiles at Uitenhage; elands all along the coast, from Bredasdorp to Albany; hippopotamus from the Berg River, at Saldanha Bay, where the last was shot by Mr. Melk about 1900; the Fish and Keiskama Rivers, and of course the "Hippopotamus" River, the Umzimvubu, where I was offered sjamboks from the hide of the last remaining animal in 1901. Quaggas and zebras, also, occurred in countless thousands.

I found at Nuy Siding, on the railway from Worcester to Robertson, a number of peculiar hillocks, made of soft, yellow soil; they were from six to ten feet high, and spread out in a wide flattened cone, with a circular base. Where the railway cut through them the hillocks showed no structure whatever. About a square mile of country was covered thickly with these hillocks, and there appeared to be no local explanation of the phenomenon; they were a great nuisance, as though the soil was exceptionally rich, it required a considerable amount of labour to level the ground to make it suitable for crops. At the time I suggested in the "Geographical Journal" that the hills were the remains of

ant-hills. Recently I traversed a forest in Ovamboland, near Kambonde's Vley, where owing to drought, the trees were dying, and also the great ant-hills were disintegrating; these latter were twenty feet high in some places, and those that were dead were slowly sinking into flattened cones of the same shape and size as the Nuy hillocks. I have very little doubt now that the hillocks are what I suggested, and they add to the proof that the south part of the country was at no very distant date as hot as present-day Africa is within the tropics.

Why has South Africa become so much colder? Many people at once refer to astronomical causes. This explanation of the glaciation of north Europe was brought forward prominantly by Croll in a series of publications, beginning in 1865, and the battle was fought furiously for a quarter of a century; the general result of the discussion was to bring out the fact that though astronomical changes did affect the earth in regard to its relationship with the sun, nevertheless there were so many compensatory effects that one could not say whether the sum of all the alterations would cause an actual change or not. Every single apparent cause was subjected to destructive criticism; as an example Croll, and more lately Nansen, maintained that ice could accumulate in the Arctic regions to a depth of several thousand feet, quite forgetting that ice melts when piled up in masses over 1,500 feet thick; as a matter of fact, no mass of ice occurs either in the Arctic or Antarctic more than 1,200 feet thick. The conservation of cold, therefore, could not go on to anything like the extent that was assumed. Generally, then, the astronomical cause for the Ice Age was not proven, and it is wrong to adduce this cause for the refrigeration of South Africa. The whole matter gained a new impetus when I was able to demonstrate by irrefutable facts, the glacial origin of the Permian or Dwyka Conglomerate of South Africa. These very old glacial beds had been described from India and Australia, but it was not till the South African beds were brought into line that it became generally recognised that, south of the equator there had been, in these remote times, a very general glaciation. Later on glacial beds, exactly resembling the Indian, Australian and African ones, were discovered in

southern Brazil. This line of glaciation, it will be noticed, crossed the equator in India, and it was at once suggested that perhaps the earth's axis had shifted; it was pointed out that if the South Pole were to lie somewhere in the Indian Ocean, then the Australian, Indian and African Permian glacial deposits would be arranged circumpolarly. Unfortunately for this suggestion, the Brazilian deposits would lie on the equator. So the idea had to be abandoned.

Having exhausted all possible astronomical causes, precession of the equinoxes, shifting of the angle of the ecliptic and of the position of the pole, and having found on careful scrutiny that none of them would explain either the glaciation of the Great Ice Age nor that of the Permian Age, nor for the matter of that the recent climatic changes, geologists turned to an altogether different line of evidence.

It was noticed that certain periods in the earth's history were marked by tremendous volcanic eruptions all over the globe; two will suffice here, the Carboniferous and the Eocene. Wherever such formations occur, the fossils found in the rocks that were laid down at the time show unmistakable tropical conditions, and these were not confined to any one zone, but reached right up to the poles. Great forests grew in the Antarctic regions, and where now lies Spitzbergen, in Carboniferous times, and their remains have come down to us in the form of coal; trees like the cinnamon and magnolia grew within the Arctic circle shortly after the Eocene. These periods were further characterised by tremendous vegetable growth, as the Carboniferous coal-beds testify, and the great forests of the Tertiary Period, a remnant of which lingered on into historic times in Europe. Also, they were periods of intense limestone building. Both vegetable growth and limestone building means abstraction of vast quantities of carbon dioxide from the atmosphere; so that, as immense volumes of this gas were vomited out from the myriad volcanic vents in the volcanic periods, so, in the succeeding periods, processes were at work removing the carbon dioxide from the atmosphere. Finally, when the air became relatively pure once again, glacial epochs supervened; after the Carboniferous period came the Permian Ice Age, and after the Eocene

period came the Great Ice Age, of Pleistocene, or recent times. The explanation of this has been put on an experimental basis by Arrhenius.*

The amounts of carbon dioxide and water-vapour in the atmosphere are mutually dependent. The dry air of the Karroo is particularly pure, and on the contrary the air in a crowded theatre, which is densely charged with carbon dioxide, is also damp and moist. With much carbon dioxide, then, from the Carboniferous and Eocene volcanoes, there went along with it into the atmosphere a much greater amount of water-vapour than is at present diffused throughout it. Both these gases blanket the earth in such a way that, as the run's rays strike through the atmosphere, a part of the heat is absorbed and retained by the gases. It is a familiar phenomenon to everyone that on a clear night the air is cold, whereas on a cloudy night the air is much warmer; this is the popular way of saying that when the air contains little moisture, radiation of heat from the warm surface of the ground is not stopped, but when there is much moisture in the air, rendered visible by the formation of clouds, then the radiation is impeded.

Arrhenius found that a total clearing of the atmosphere of carbon dioxide would reduce the average temperature of the globe by 14.6 degrees Centigrade; the precipitation of all water-vapour, which would follow as a secondary effect, would entail a further reduction of 12.5 degrees C., or 27.1 degrees in all. In degrees Fahrenheit this would be 48.8. Suppose the clearing of carbon dioxide and water-vapour was only about half of this, and the reduction of temperature was also only half, or in round numbers 25 degrees, then, no place outside Natal within the Union of South Africa would show a single month in the year without severe frost. Even at Durban, only three months in the year—January, February, and March—would be without frost. As a matter of fact, a lowering of the average temperature of 8 degrees F. would induce all the glacial effects shown in the Great Ice Age.

* I have dealt fully with this aspect of the case in "Causal Geology," page 129.

Contrariwise, to produce the world-wide tropical effects of the Eocene tropical conditions, would require an additional temperature of 16 degrees F.; this could be induced by increasing the carbon dioxide in the atmosphere three times the present content, or about twice if we allow for the additional water-vapour that would be held.

I have gone somewhat deeply into this question, as there are many small, popular books that give some part of the astronomical causes for the Great Ice Age, and from these many people have concluded that the refrigeration of South Africa is a result of cosmic processes that no effort of man can control. As one who was responsible for much of the later evidence connected with past Ice Ages, I went through the whole of the arguments, and the facts presented to us from the geological and geographical distribution of the glacial epochs show that the composition of the atmosphere has a controlling influence on the temperature of the climate.

All this goes to show that when the Kalahari Lakes dried up, the water-vapour supply of the atmosphere was cut off; with this the holding capacity of carbon dioxide was diminished, and the lessened amounts of the two gases combined rendered the atmosphere so clear that radiation of heat from the surface of the ground became unimpeded, and the result was a general lowering of the temperature throughout.

Irrigation not sufficient.—The remedy for a country subject to arid conditions is to irrigate; we have the ages-old examples of Mesopotamia and Egypt. More recently we have the highly successful irrigation projects in America, though we shall shortly see that these are not financially sound. An impartial review of the efforts in the matter of irrigation in South Africa obliges one to come to the conclusion that they have not come up to anticipations. I propose in the present section to examine some of the causes for the want of success; I am not a pessimist, and I do not want in any way to hinder, obstruct, or in any way spread disparaging views in regard to the irrigation policy at present being pursued in South Africa, but from my wide knowledge of the conditions prevailing in the Union I can

show where all these projects will fail after a time, and none of them will realise expectations unless something is done to remedy the growing aridity of the climate.

One of the most typical examples is Van Wyk's Vley, because it so quickly went through the normal cycle of evolution, and realised the adverse conditions under which all such projects must labour; all other schemes must go the same way, although the period of usefulness may be extended. Van Wyk's Vley is in the high Karroo region, in the district of Carnarvon, where the ground is very flat, and the rivers naturally spread out into vast shallow pans or "vloers," so that a comparatively small wall will throw back the river for many miles, and impound a very large quantity of water. The work was finished in the eighties, and soon after the water was led on to the land, brak appeared and killed the crops. Large areas are now abandoned near the wall, and have been planted with the Australian Salt bush. Irrigation is still carried on on lands a considerable distance from the wall, but the returns are extremely disappointing. The works cost £25,000, and the revenue in 1917 was:—for irrigation, £26; grazing fees, £154; salt, £50; miscellaneous, £7; total revenue, £237, or less than 1 per cent. on the capital expended. For 1918 the figures are better, in fact, the best on record; they are respectively £582, £288, £58, and £18, total £944, or something less than 4 per cent. It will be noticed, however, that from water rates and rent of plots, only a little more than 2 per cent. was earned, the rest was eeked out with the gathering of salt and grazing on the unirrigated lands. In 1917 the revenue derived from irrigation was one-tenth per cent. Maintenance expenditure for these two years was £341 and £435, so that in 1917 there was a loss of £194, and in 1918 a gain of £509. The two years given above were respectively a good and a bad year, and all irrigation projects are subject to the same conditions.

In the larger schemes it is hoped that so much water will be conserved that the irrigators will be independent of droughts. Experience, however, shows that this hope is illusory. At Bloemfontein a great storage reservoir was

built to hold three years' supply; the drought of 1919 came, the water level was all right, when one day someone visited the dam and found it drying up. What had happened was that the dam had silted up, and no more than a six months' supply had been impounded. An analysis of the causes that render irrigation unsuccessful in South Africa shows that they fall under three heads:—(1) the areas irrigated are so small in comparison with the vast stretches on either hand of parched land, that desert conditions are unrelieved, and a bad season will destroy crops, plantations, and generally the organic structure of the soil, so that the areas irrigated cannot recover. The least careless handling of the plots, even in normal years, may lead to the total infertility of the soil. (2) Following on the last, the air is so dry, that water that sinks into the ground is quickly drawn up again by evaporation from the surface, and the salts that are present in all arid soils are deposited in a crust within the growing zone of the crops, and the soil is rendered "alkali," or "brak." Chemically it is possible to remedy this, but the process is doubtful, and at anyrate expensive, and in practice has not proved a success in South Africa. If one can get rid of the aridity, then the danger of brak disappears automatically. (3) Owing to the peculiar nature of the rocks of which the greater part of South Africa is composed, there accumulates on the surface of the ground in the dry seasons an enormous quantity of fine broken-up rock fragments, not merely sand, but small bits of shale that can be washed down the rivers and carried by the rush of the waters. In the first flood after a rain, therefore, the rivers carry streams of liquid mud, rather than of water, and all dams are therefore liable to be filled up with silt, as happened actually in the case of Bloemfontein. We will examine these factors a little more closely.

The extent of the arid land in South Africa.—We can take it that, except for very small patches along the coast, such as the eastern side of the Cape Peninsula and Knysna, there is a deficiency of moisture over the whole of the Cape Province; the same applies to the South-West Province, to the Bechuanaland Protectorate, which is virtually the

Kalahari, to the Orange River Province, and the Transvaal for about half its extent.

Area of land in South Africa over which there is a deficiency of moisture.

	Square Miles.	Acres.
Cape Province...	277,151	177,134,884
South-West Province..	322,450	206,368,000
Bechuanaland	386,200	245,168,000
Orange River Province... ...	49,950	30,968,000
Transvaal (½)...	56,821	36,365,440
TOTAL	1,092,572	706,004,324

The irrigated land in the Union is about 600,000 acres, and the present works, when completed, will add some 150,000 acres to this total; the whole area is well under one million acres, or less than one-seven-hundredth of the total area over which there is a deficiency of moisture, and which is hungering for what little moisture is available. No amount of irrigation and impounding of water on the ordinary scale will have an appreciable influence on the climate of South Africa. Nor will it relieve the social position, for the expensive irrigation schemes will not allow the poor man to come in except as a labourer, which is not satisfactory, in view of the cheap native labour with which the white farm labourer would have to compete. Whether the rich man will succeed is another matter; he ought to, but as a matter of fact, unless he is able to command exceptional conditions, such as the monopoly of the ostrich industry, or famine prices owing to failure of supplies due to war, drought or shipping difficulties, he does not. What happens is that a progressive farmer irrigates from a river; drought comes and he fails, and sells out at a loss. The new owner obtains expensive improvements at less than cost price, and may succeed on the reduced capital. I live in

close touch with an irrigation community on the Great Fish River, and have seen so many heartrending failures of the most promising propositions, and have so often talked with men experienced in irrigation in the Union, and seen the state of projects in all parts, that I say deliberately that, under present conditions, irrigation under the best circumstances is not a commercial success. One must not take into account the successes of land speculations. I am referring to genuine farming.

The Kalahari scheme will produce areas of impounded water and irrigated land to the following amounts:—

Area of water and irrigated land on the Kalahari Project.

Etosha Pan...	5,000	square miles
Makarikari Lake...	15,000	,,
Irrigated land...	10,000	,,
TOTAL...	30,000	,,

This, compared with the 1,000,000 odd square miles of land in the Union, over which there is a deficiency of moisture, gives 3 per cent. If we add the 70,000 square miles of Ovamboland restored to fertility, this becomes 10 per cent. Taking the transpiration from irrigated lands to be the same as the evaporation from the free surface of water, and assuming this to be the same as the figure given for the Johannesburg area, namely, 90 inches, this alone would give an additional 2.7 inches of rain for distribution all over South Africa, or, with Ovamboland, 9 inches. The percentage of irrigated land works out at .14, giving a total addition of rainfall for the dry area of South Africa of .13 inches of rain; not enough to be thankful for.

Actually, more water-vapour is transpired from most of the usual crops grown in South Africa, than from the free surfaces of water; I give the following amounts in my "Causal Geology":—

Amount of water-vapour given off from free water-surfaces and from the leaves of various plants.

		Per square Metre per Month.
Evaporation from free water-surfaces,	maximum	144.8 kilogr.
Lucerne	,,	203 ,,
Meadow grass	,,	218 ,,
Oats	,,	147 ,,
Mealies	,,	119 ,,
Wheat	,,	83 ,,
Potatoes	,,	41 ,,
Oak trees	,,	28 ,,
Vines	,,	26 ,,

These are European measurements, but the relative amounts would not be different under South African conditions.

There is another way of looking at irrigation projects; as a rule, in normal years, only a fraction of the water that pours from the catchment areas is impounded. Take the Fish River as an example.

Comparison of amount of water flowing from the catchment areas and the water impounded in reservoirs.

Great Fish River Area.

Figures represent million cubic feet.

	Yield from catchment.		Impounded.
	Maximum.	Minimum.	
Grassridge	4,220 (1900)	85 (1908)	12,725
Baviaans River .	910 (1913)	270 (1903)	887
Tarka River... ...	4,100 (1917)	346 (1908)	3,606

Note the enormous difference in the yield in the Grassridge catchment area.

The estimates are for the dam before the water is impounded; no estimates are available for what the capacity is likely to be after, say, five years. In one or more of these five years, the total wash from the country will be impounded, including all the rock waste and silt, and in any case, the first waters, containing the bulk of the detritus from the land, will settle in the reservoirs. Knowing as I do the Great Fish River, I am within the estimate when I put the permanent holding of the reservoirs at one-third of the calculated capacity. At Bloemfontein it worked out at one-quarter for Mocke's Dam, and a little more than one-half for the lower dam, Mazelspoort. Even at Grahamstown, where the catchment area is covered with soil, and the surface protected with dense grass, the reservoirs have silted up very badly, and any Karroo catchment area must give far greater amounts of silt. Another example is the great dam at Beaufort West; this became practically a level plain of mud, and was cleaned out at great expense. I have no details of the expense of removing the deposit, but in this case the railway helped by lending rails and trucks for the removal, and in this way reduced the expense. It may be taken, as a general rule in these cases, that the cost of scooping out the great accumulations of silt, which pack almost into a rock, is not very much less than the prime cost of building the original wall. The estimate for removing the 3.1 million cubic yards of silt in the Bloemfontein dams was £60,000, and one method of removal suggested would have required 240,000 days. I shall refer to the question of silt again; the point I wish to make here is that in ordinary irrigation works, the water impounded is not all that runs down the catchment area, but usually a very great amount of the water runs away to the sea, and is lost. By keeping on weiring up a particular river, the amount eventually impounded will bear some reasonable relation to the water that is supplied in rain. Only a very few rivers in the country will pay for this treatment, and we come back to the old contention, that irrigation will make no appreciable difference to the country. In the case of the Kalahari scheme all available water will be impounded in the vast natural reservoirs, until such time, when by reason that no

more water is required, the surplus will flow down its old channels to the Orange River, and so out to sea. There is no fear of turning the area into a salt marsh, as these rivers bring down very little salt. There is none in the Etosha Pan, and there is only a slight saline incrustation on the surface of the Ntwetwe and Soa Pans, which is the accumulation of centuries.

Why it is important to impound all the water is that such water is added to the permanent stock of the country. A certain amount seeps away and strengthens the natural springs; the rest is evaporated, either from the surface of the water, or from the irrigated land, and is diffused into the atmosphere. Then when winds blow over from the sea, the air is well supplied with moisture, and the added moisture of the air from off the ocean allows the precipitation of rain. In this way the water is used over and over again, and the stock of the country is maintained at such a level that all requirements are met; after that the surplus blows away over the sea and is there precipitated. With irrigation we only stop a fraction of the water running to waste, and the draining of the country of its most precious capital asset, its water, goes on with the merest fraction of the required stoppage. We shall see in the sequel how plentiful rains are cumulative in their effects on the country, and the improvement being in a geometrical rather than an arithmetical progression, so that once one obtains a unit irrigation scheme large enough to make an impression favourable to the country, the amelioration is marked and rapid. The converse is likewise true. Droughts are cumulative in their results, and as long as there are no projects completed that are of sufficient size to combat and master the drought conditions, then the latter will become emphasized year by year. To put it another way: the small irrigation schemes will, perhaps, allow for a limited number of individuals to thrive along the few rivers that are weired up; the rest of the country is going backwards, and no benefit will accrue to it, and the process of drying up will go on till the country, as a whole, will become uninhabitable.

Brak.—This word "brak" is an ominous one for South Africa. It is, briefly, the salts of soda and lime that have accumulated in the growing zone of the soil to such an extent that ordinary plants are killed. Certain plants are adapted to these conditions, like the Ganna, or salt wort, Salsola, of the Cape, and the various salt bushes of the alkali belts of America, the deserts of Asia and Australia. Certain other plants are resistant to brak, such as the beetroot and lucerne under certain conditions, so that, by judicious selection of crops, brak soil may be rendered fit to support the less resistant crops by the action of these others. In natural soil, when water soaks in from the rain, some of it will return to the surface and evaporate, leaving on the surface an incrustation of white salts, often called an efflorescence. When irrigation water is led on to the same ground, the action is intensified by as much as the waterings exceed the rainfall. It is by no means rare to flood the fields with water to six inches in depth, and 12 inches are sometimes employed. The led water tends to leave on the surface a hard crust, which is in continuity with the soil below, so that capillary attraction is continuous from the lower layers to the surface; the consequence is that as the surface dries and becomes hot, water is drawn up from below, and evaporates in turn, and the process becomes continuous. Rain falls gently, and one does not find that this hard crust forms to the same extent. The chief reason, however, why irrigation water causes the development of brak to such a much greater extent than rain water, is that, when the rain falls, the atmosphere is more or less saturated with moisture, so that the water sinks in and drains slowly away, or finds its natural channels, that is, the surplus that is not required for rendering the soil fertile. If water were to be led under the same conditions, then there would be no brak; that is what the Kalahari scheme will do. The atmosphere will be charged with sufficient moisture to prevent the rapid rise of the water that has entered the soil. As it is at present, irrigation is usually undertaken when the air is at its driest, and immediately it draws on the moistened earth to supply its own lack of humidity; the air is like that in a reverberating furnace, and the consequence is that the soil-water is depleted rapidly,

before it can reach depths where it might escape the action and the contained salts, common salt, sodium sulphate, sodium carbonate, lime carbonate and gypsum, are deposited between the grains of the soil. At first the deposit is diffused in the critical zone, 15 inches below the surface, but as the process advances, the salts mass into definite layers called "hard pan," for which there is practically no remedy. Brak in the diffused state is not so bad, and extraordinary results have been obtained in America by judicial treatment of brak in this condition, especially in the Saltern Sink, at the head of the Gulf of California.

The surface crust prevents seedlings from making headway, and also deprives the surface soil of aeration necessary for plant-growth. This can be dealt with by "mulching," that is, by raking over the surface and creating a layer of loose earth. The continuity of the surface soil with the lower layers is thereby destroyed, and the capillary rising of the water is stopped. There is, however, a more dangerous zone in which the salts are deposited; this lies some 15 inches below the surface. It is caused, not by the direct action of the sun's rays, but by the drawing on the water content of the soil by the dry air. The action is similar to that of an apple or potato that is exposed to dry air; the fruit shrivels because of the loss of moisture. This is the real brak zone that destroys the fertility of the soil.

There are many methods of treating this kind of brak. The ancient Egyptian method was to make the fields slightly higher than the surrounding country; then, when they were swamped at high Nile, or by having water lifted on to them, the water soaked through and drained off into ditches cut round them; the brak was thus carried away. This method requires a very large amount of water, and cannot be employed where high water rates have to be paid. A further method is to run ditches, at a depth just below the level of the brak zone, through the fields down to some lower level; these are then filled up with boulders and covered in. When the water is led on to the land, after supplying the necessary moisture to the soil, the surplus drains into the covered ditches, and trickles away between the boulders. Here

again, very much more water has to be employed than is required for the production of crops. I have seen in Oudtshoorn, fields drained in this way, watered with what was practically brine, with beneficial effect; the lucerne here had been long established, and I doubt whether it would have succeeded with younger plants, whose roots had not penetrated so deeply.

Every country has its special problems in brak, and what succeeds in one country does not necessarily succeed in another. Take the "kankar" of India, a brak caused by the deposit of lime in the soil. Messrs. Evans and Taylor, of Cloverfield, Mortimer, on the Great Fish River, write:—"Our soil is ordinary whitish alluvial deposit, varying from 12 inches deep over lime, to 30 inches deep over gravel. It might be of interest to say that we have had excellent returns from ground 8 inches deep and less, underlain by hard white lime in solid slabs, where, so far as we know, no roots could penetrate. We used an Elephant plough to break the ground, and when the lucerne was sown the ground was covered with big chunks of limestone; the seed was thrown on the surface and watered in. Kaffir women placed this limestone on the banks of the plots. On this class of ground we cut over one 12-acre section thirty tons of hay in one cut. This lucerne continued to crop well for four or five years, and then our water-supply become considerably augmented by the Government furrow; we were tempted to thrown too much water too often, and from want of experience of not differentiating between shallow and deep alluvial soils, we completely killed the best portion of this stand, which looked like going on for years. Funnily enough, the portions killed were those sections where the soil average 6-8 inches deep, while those sections where the lime is only 2-3 inches below the surface are alive to-day, and still cropping well, after six or seven years."

This passage shows the extreme care that must be exercised in dealing with irrigated land; it has happened again and again that brak has risen on shallow soil by excessive waterings. In deep soil it is usual to allow practically unlimited water to run on to the land, and I have

seen water draining from such land weeks after it had been watered, showing proper drainage. Owing to the scarcity of water and the high water rates, it is customary to make the lands dead level, and to run on the water to some 3 or 4 inches. In such cases the salts accumulate in the brak zone, 15 inches below the surface, and these aggregate into a hard pan. Then the effective soil is only that lying above the hard pan, some 12 inches in all, and all the disadvantages of shallow soils are engendered. Very shortly such soil becomes absolutely infertile.

The most deleterious form of brak is that caused by sodium carbonate, the "black alkali" of the Americans. This can be treated with gypsum and turned into "white alkali," or sodium sulphate. So, with suitable crops, draining and chemical treatment, brak soils will yield to skilful management, *provided that normal or good seasons help*. With drought conditions the handicaps are too severe, and in practice it is found that just when the treatment promises success, a long spell of exceptionally dry weather or a succession of scorching winds upsets everything. From the statistics given above, when for the last 23 years there has been only two good years, it is manifest that the conditions for dealing successfully with the problem of brak are most discouraging. The spread of brak is going on in all irrigated lands, and everywhere one hears the cry for Government to urge their experts to devise some method of dealing with it. As long as the air is so extremely dry, nothing can be done to check the spread of brak; once the air is rendered less arid, then at once remedial methods can have a chance of success, and with the Kalahari scheme in full working order, the whole nuisance of brak will disappear.

Brak need not necessarily be the outcome of irrigation; some of the worst brak soils are those forming on the dolerite outcrops in the Transkei, where there is a sufficiency of rain. Here it is the chemical composition of the parent rock that is the trouble; the dolerite decomposes under the usual atmospheric conditions, and sodium carbonate is formed in considerable quantities. The soil under such circumstances is a dead black loam, quite infertile, even for the ordinary

veld plants and grasses. Additional rainfall and atmospheric moisture will not cure this type of soil alone, but with suitable treatment with gypsum the deleterious content can be changed into a comparatively innocuous one, and the land can be converted into an extremely fertile tract.

Silt.—The question of silt is one that has troubled every engineer dealing with arid or semi-arid regions, and it has special difficulties for us in South Africa, because most of our rivers are intermittent. The best method to overcome the difficulty is to have sluice-gates opening up from base to crest of the wall, which can be raised when the water is dirty and the mud and silt pass through; then, when the clearer water comes down, the gates are lowered and the dam is filled with water only. If there is any deposit, the next time the gates are raised, the rush of water carries it way. It has been found necessary to make such provision in the case of the Nile dam at Assouan and in the Vaal River Barrage, below Vereeniging, which is to supply Johannesburg with water, sluice-gates are likewise employed. Reservoirs on this principle are exceedingly costly, running into millions of pounds, and are entirely out of the question when irrigation is the sole object of the scheme, unless it be on the vast scale as in Egypt. In America, Mr. Lawford has elicited the opinion of Professor Etcheverry on the subject:—"Regarding the deposit of silt in reservoirs, I know of no remedy. It is usually impossible to prevent it, and there is usually no feasible means of scouring out or removing the silt which accumulates in reservoirs. There are a number of reservoirs in this country where silt deposits are considerable, and the only solution will be to create new storage by raising the dams or by new reservoirs." In America, Spain, Mesopotamia, and India the streams are fed from mountain torrents, often, if not mostly, obtaining their supplies in spring from the melting of snow, when their waters are clear and abundant, and can be used for scouring out the previous year's silt.

There can be no possible parallel between such rivers and, say, for instance, the Great Fish River, where the whole catchment area is for months absolutely dry and undergoing

disintegration under sweltering heat alternating, in the night time, with intense radiation, if not actual frost. At Lifford, on this last river, there is a weir turning the water into a dam above the lands, and from which all irrigation water is drawn; I have seen the river coming down so charged with mud that it was impossible, for days, to impound any water. By the time that the stream had cleared sufficiently, the flood had subsided, and very little water could be turned into the storage dam. Irrigators up the river, who used pumps, in desperation tried pumping this muddy water on to their lands, with the result that large areas of lucerne lands were destroyed. I remember vividly being once nearly caught in one of these Karroo rivers that came down unexpectedly, after being dry for three years. It was the Gamka, below Prince Albert. I heard that the water was coming down, and walked across the bed, which was 200 yards wide, and saw on the far side a small stream of veritable water; hearing a noise up-stream, I looked, and saw a great wall of mud, ten or twelve feet high, advancing with great velocity, and crashing and clashing stones, sticks, dead sheep and oxen, bits of houses, and all manner of debris. There was a fore-foot of grey water, perhaps twenty yards wide, in front of the main wall of the mud rish, and I ran for my life along the edge of this fore-foot, and scrambled up the banks only just in time. As I pulled myself up by the mimosa branches, the whole flood swept by me, seething and boiling with an incredible din. Within a few minutes the river was running bank-full. It is impossible to obtain exact figures for the amount of silt that was carried by this river, but I think, considering that there were three years' accumulations of rock waste to be got rid of, which had all been washed down by the impetuosity of the torrential downpour, a fair estimate would be that an inch of rock waste, distributed over the catchment area, was carried down. The catchment area is about 4,000 square miles, then on this estimate, nine thousand million cubic feet of silt was borne by the flood. I think this estimate is of the correct order of magnitude, from my observations on the Great Fish Fiver. In the particular flood that I referred to before, the rains came down in summer floods after a year's drought; the water was in the

proportion of 2:1 in respect to the silt. As the velocity of the river falls, the water clears, and a large part of the silt in suspension is dropped; it continues to move downwards, however, along the bottom of the river, and it is no exaggeration to estimate the whole flow of the river, taking into account the silt in suspension and the silt dragged along the river bed, as being composed of two-thirds water and one-third silt. If the river were to start flowing again for months at a time, then the above estimate would not hold, but I am taking the river as it is to-day, when it runs in fits and starts, for a week or so at a time, and each flow being the result of a sudden and short burst of rain.

The rainfall for the year is about 17 inches, in very good years 20; taking the latter figure, and assuming that the run-off is 5 per cent., which is a little high, we obtain an effective run-off of one inch from the whole of the catchment area. This run-off as it passes down the river is composed of one-third silt, and we thus obtain an estimate of the amount of rock worn off the surface of the Karroo of one-third of an inch in a year. Applying these figures to three catchment dams that are to be built on the Great Fish River, we obtain the following figures:—

Estimated Silt carried by the Great Fish River, compared with the capacities of the proposed dams.

	Catchment area, sq. miles.	Estimated silt; Millions cubic feet; annual discharge.	Capacity of dams. Millions c. ft.	Apparent life; years.
Tarka River	2,270	1,747	3,606	2
Grassridge...	1,583	1,225	12,725	10
Baviaan's River ...	336	260	887	3

By "apparent life" is meant the time required to fill up the dams with silt. I have taken these figures, not with

the object of criticising these particular projects, but because the figures are handy, and enable one to obtain some idea of what usually happens in similar structures. As a matter of fact, there are sluicing devices introduced into the schemes, which are rather doubtfully expected to in some way get over the silt trouble; similar sluicing arrangements are a success in the Moorish dams in Spain, which have been in existence for five centuries. The silt in the particular dams referred to, in the province of Alicante, become filled with silt from the waste from the loose Tertiary rocks of the eastern side of the Peninsula; they produce a sediment that does not pack like our Fish River muds, so that when the sluice gates are opened, the silt is drawn down by the current and washed out. In the Karroo, walls of sediment, 30 to 50 feet are exposed on the river banks; formerly they used to be protected by dense growth of mimosa trees, whose roots held the soil; now these trees have been mostly cut down for fire-wood, and the bare cliffs of muds withstand the tearing action of the river in flood, almost as if they were made of rock. The silt referred to above, by Messrs. Evans and Taylor, had actually turned to solid limestone. In the Vaal River barrage, 36 gates 30 feet high have been considered necessary; in the Grassridge dam, on the Fish River, where the silt is far greater than in the Vaal, only three are provided.

The reasons why our silts will not sluice are:—Firstly, the Karroo waters are heavily charged with lime and alkalies, which in the extreme arid conditions of the atmophere prevailing, dry out and cement the silt into hard, intractable masses. Secondly, the flow of the rivers is intermittent; for months there is no flow at all, and then, when the water does come, it is only for a few days. The dry periods allow the silt to settle and consolidate. Thirdly, the period during which the water retains its velocity, sufficient to sluice, is extremely limited, and after the river has passed in flood, there is no more water to follow on and complete the action of the first burst. Fourthly, the water when it does flow, is so foul, that it is semi-viscid; the liquid part of the total volume measured as "water" is so small—

I am assured that my estimate of two-thirds is often too great, and that half silt and half water is nearer the mark—that the muddy stream has all its work cut out for it in getting a move on, and that if it were to sluice down more silt, the flow would stop.

I have seen silt carried into a hollow in the Keurbooms River in Knysna, above De Vlugt, where the nature of the river is more comparable to that of the coastal rivers of Spain; the sediment accumulated in one flood to such an extent that a buck waggon, twenty feet long, turned upright, was entirely buried, and the owners thought it had been washed out to sea. In the next flood, the whole of the silt was washed out, and the waggon exposed in its extraordinary position. The silt in this case was obviously loose, although the period between the two floods was ten years; the rocks from which the sediments were derived were old sandstones and slates of the Table Mountain and Bokkeveld series. If this action were to go on in the Karroo rivers, there would be no alluvium left on which to lead the water for irrigation purposes. Loose friable rocks, similar to the Oligo-Miocene rocks of Spain, which cause the silting trouble, are found in neighbouring rivers in Knysna, the Pisang, and Bitou rivers, but I have no observations as to the sluicing qualities of the sediments, but they are there for purposes of experiment and observation.

The figures given in the table above are obviously excessive, even for reservoirs without sluicing devices, and the reason for this is that after the dams are filled up to about three-quarters of their capacity, the surface current is sufficient to keep the sediment stirred so that it goes over the lip of the spill-way, and disappears. In the deep portions of the dams, the water on top may have a considerable velocity, but here it is quite still, and settlement of sediment goes on as if the whole body of the water was at rest. A certain amount of silt, too, is clay, that only settles at all when in contact with salt, gypsum or alum. At Bloemfontein the limiting loss of capacity appears to be 75 per cent.; this is the extent of the infilling in Mocke's dam, which acts as a straining dam. Mazelspoort has filled to 45 per cent.

of its capacity, and now that the straining dam is not taking off any more silt, or at any rate, only a very little, the process of filling up is going on apace. After a dam has filled up to its 75 per cent. limit, then the further filling is slow.

The above arguments are not in the nature of captious criticisms on what are excellent projects; they are meant to show the dangers of silt, and the financial loss that is certain to result from the building of these reservoirs *under present conditions.* The cost to the irrigators is calculated on the amount of the water with which they are to be supplied; if only one-quarter of this water is available owing to silt, then there will not be enough revenue to pay for the interest on the outlay. My remedy is to restore the moisture in the air to the amount that existed in it before 1820, when the Great Fish River, among a host of other Karroo rivers, ran ten months in the year, and sometimes all the year. The result will be:—

(1) Steady rains instead of sudden bursts.

(2) Clearer water.

(3) No veld erosion.

(4) Protection of surface by continuous vegetation.

(5) No brak.

(6) No need to irrigate, except for special crops.

The Kalahari Scheme is capable of effecting this change. There are a host of other suggestions, but none of them are effective in practice. The scheme adopted by the Government is to conserve the smaller rivers, and so gradually induce better conditions. With the present schemes completed, the area affected will be less than .0014 of the total dry area; the Kalahari scheme, with its free water surfaces and irrigated lands, will provide .03 of the total area, or with Ovamboland added, one-tenth. There are no lands suitable for irrigation to an extent anything approaching .1, or even .03 per cent. in the Union; the latter figure would mean the irrigation of 20,000,000 acres. Unless the improve-

ment is effected to this amount the benefits will not become appreciable, as the vastness of the dry lands will undo the labours of the irrigators and ruin them. If 200,000 acres are drawn into irrigation schemes a year—a very high estimate—it will take 100 years to effect the improvement, supposing it were possible, that my Kalahari scheme on the lower estimate will achieve. The crux of the whole position, however, is that a large proportion of the schemes, without the Kalahari scheme, will turn out to be other Van Wyk's Vleys; they will be failures, and before the necessary total of projects are completed sufficient to make an impression for the good on the country as a whole, the people will be discouraged and the country bankrupt.

There are alternate suggestions, but none of them are effective in practice. Some say plant trees. Well, large sums of money have been expended in such planting; the trees thrive for a time, then comes a drought like that of this year, 1919, and the plantations are killed. I refer, of course, to districts with less than 20 inches of rain, where desert conditions are increasing. Others say, stop up all the spruits with bush and rubble dams. This is good advice, but how can one obtain labour—to take only one item—to effectively stop up all sluits over an area of 1,000,000 square miles, and a little here and there will do no good to the country as a whole. Innumerable rain-making scheme have been brought forward, such as scattering dust in the air from aeroplanes, or by building towers and spouting secret chemicals into the air from the tops, or again, discharging electricity into the air from poles. All of this class depend, even were they practicable, on moisture in the air, without which one cannot bring it down.

Mr. F. Gessert, dealing with this aspect of the question, writes:—"What would be the consequence? Every farmer would have his kite for delivering electricity and dust in the cloud regions. A jolly air war would begin, similar to the late water war at Klein Windhuk, where the neighbours tried to drain the water, by always deeper tunnelling of the mountain, from their neighbour's erf. Likewise every farmer would endeavour to send up the bigger kite, with stronger wires and more dust, to win the rain. With what right? To what height does the ocean of air belong to the

ground proprietor—to the top of his wind-mill, or as high as his kite will rise? As the rain requires time to fall, some farmers ought to begin rain-making above his neighbour's acres to have success. Is he to be allowed to do so? One farmer would accuse the other of having stolen his rain; what did fall would have fallen in the ordinary course of events on the first one's kopje. There would be an action for damages. A large number of very interesting law questions would spring up, and it would be a good time for meteorological attorneys. Where goodwill was not sufficient, affairs would have to be settled by compulsion. What would be the result? Would the country's whole sum of rain have been augmented? Perhaps. Do the mountain ranges that separate the coast-belt from the high plateaux of the interior augment the rainfall of South Africa? Locally they do considerably, but on the lee-side of the mountains the drought is worse. Sometimes a mountain may bring clouds to the point of precipitation, and these proceeding on their way will rain over the plateau as well. Likewise, kites sometimes, possibly, will accelerate rain that otherwise would have fallen later. The year's sum of rainfall is dependent on the quantity of vapour that is brought by the winds over the boundaries of a country, or that evaporates out of the water flowing into it, and upon the figure that indicates how often this vapour is precipitated as rain before leaving the country as vapour or water. This figure may possibly be augmented by artificial precipitation. It is, however, of the same or higher importance, that the vapour and water circulating in a country should be increased, or that the run-off of the water should be impeded. That is the reason why the formation of the Kalahari Lakes is the first consideration of a pluvious South Africa."

American experience.—We look so confidently to irrigation to solve all our trouble, that it may be as well to refer to the experience gained in America; a very excellent summary has recently appeared in the "Geographical Journal" for October, 1919, a digest of which was published in the "Field," November 8th. I give Professor Whitbeck's conclusions. "It is fully established that it costs more to produce crops on irrigated land in the United States than it does on good land under rainfall. Before the war, the United States Reclamation Service reckoned that the average 40-acre irrigated farm involved an invested cost of money and labour of about £2,000, or £50 an acre. In Utah the Department of Agriculture studied 69 farms, old estab-

lished enterprises, averaging 50 acres in extent, and found the average investment was £35 per acre, or £1,750 per farm. The gross receipts were a little under £300 a year per farm, and the cash expenses involved averaged about £120, leaving the farmer only £180 for his own work and his return for the money invested. Assuming the figures to be representative, it seems clear that general farming under irrigation offers the average farmer little more than a living for his labour. As in other occupations, the good manager succeeds and the poor manager fails. There are, however, conspicuous cases of success, especially among fruit-growers. A very large part of the fruit grown in California is cultivated under irrigation, and many of the fruit-growers have become wealthy. Any quantity of the most luscious fruits can be grown in this sunny western climate. The production can be increased enormously, as fast as the market will take it. Unfortunately for the gruit-growers, over 80 per cent. of the population of the United States is in the east, while the most productive fruit lands are in the far west. The result is that the western grower often sees quantities of the finest fruit rotting on the ground because there is no profit in marketing it. To avoid this waste, fruit is preserved in tins or is dried. California is also developing on a large scale the production of fruits and nuts which are not quickly perishable, and can be shipped by less expensive modes of transportation than the fast fruit trains of specially constructed refrigerator cars. For example, California produces from 20,000,000 to 30,000,000 lbs. of figs, nearly as many olives, 30,000,000 to 40,000,000 lbs. of almonds, peccans, English walnuts, etc. Most of the irrigation in California is under private control. It has been in progress more than fifty years, and there is no question of its success.

"The position in some other parts, howover, is different, and if the question be asked in general terms: has irrigation in the United States been a success? the answer, in Professor Whitbeck's opinion, is neither Yes nor No. It has been an unquestionable success in many of the 55,000 separate enterprises; it has been a reasonable success in a still larger number, and it has been a financial failure in many. The

boom given to irrigation in general by the passing of the United States Reclamation Act of 1902, followed by an enormous amount of advertising, led to the undertaking of many corporate enterprises, whose stocks and bonds were mostly sold between 1902 and 1912. Many of the enterprises failed, and of those that are still operating few, if any, are paying any return on the capital invested. In nearly every one of the United States Service projects, there are large areas of land which the Government is prepared to irrigate, but people are reluctant to take up the land and assume the charges assessed against it to pay the cost of building the irrigation works. On several of the projects more than half of the irrigable land is unused. Had the Reclamation Service projects been obliged to finance their cost as private projects are financed, all would have gone into bankruptcy. All of the money which the Government has been able to collect from the water-users would pay but a fraction of the interest charges alone. The majority of the projects are not paying to the Government operating and maintenance costs. Were the Government officials to insist rigidly on compliance with the laws and contracts, large numbers of irrigation farmers would be ruined. The Government has no choice but to be lenient or to see many of its undertakings fail. These irrigation works have been expensively constructed; their cost has been far greater than predicted when the Reclamation Law was passed. The result is that the lands are not in pressing demand, and at the present rate of taking up these lands by settlers, ten years will elapse before the irrigable lands already awaiting occupancy are completely occupied. The Reclamation Service has already spent about £20,000,000 received from the sale of public lands; it has borrowed £4,000,000 more, and may shortly be compelled to seek further Government aid to maintain and complete the projects already under way."

America had its Kalahari Scheme in the form of great lakes that at one time occupied a large area of the Great Basin; the limits of these, called Lake Lahontan and Lake Bonneville, have been mapped, but unfortunately for America there are no big rivers flowing past the depressions, like our

Cunene, Okavango, and Chobe Rivers, and the scheme, though thoroughly investigated, had to be abandoned. The remnant of Lake Bonneville is the present Salt Lake of Utah, and the drainage channel, now divorced from its original supply, is the Colorado River.

Silt in European Rivers.—For comparison, and to emphasise the difference between the conditions prevailing in our rivers and those in other countries, the following figures are of interest:—

Silt carried by rivers in other parts of the world.

Rhone, at Lyone	.003 per cent.
,, ,, Arles	.007
,, ,, Arles	.007
,, ,, ,, in flood	.217
,, ,, ,, maximum measured ...	1.111
Po	.333
Vistula, maximum	2.000
Rhine, Holland	1.000
,, Bonn	.006
,, ,, turbid	.010
Meuse, maximum	.047
,, minimum	.001
Elbe, average	.013
Danube	.012
Durance, maximum	5.000
,, minimum	.050
Garonne	.500
Avon	.250
Ganges, flood	.123
,, mean	.090
Irrawaddy, flood	.060
,, mean	.017
Yangtse	.045
Plate	.012
Nile	.047
Mississippi, average	.034
Fish River, estimated	33.333

The estimate for the Fish River, of $6\frac{1}{2}$ times that of the Durance, or $16\frac{1}{2}$ times that of the Vistula, is not excessive; it includes both the "travelling" silt as well as the suspended silt. Mr. Plows, of Port Shepstone, took me to a house, built on the side of a hill. Opposite the house was a hill composed of Karroo rocks, similar to the beds in the Great Fish River valleys. On the other side of the hill was a church, and from the verandah of the house, about six feet of the steeple was visible, surmounted by the iron weather cock; seven years ago a photograph was taken from the same spot, and only the ironwork was visible. As the crest of the intervening hill was approximately half-way between the house and the church, the observation showed that three feet had been denuded away in seven years. Anyone familiar with the rapid surface changes that go on in a few years' time in the Karroo, will admit that one-third of an inch a year is quite within the bounds of reason. The value of the above list is that it brings out very clearly that European, Indian, or American rivers form no basis whatever on which to found arguments with respect to South African rivers, that is to say, in the Karroo. In the grass-veld of the Orange River Province, I would estimate, at a guess, that the denudation was about half that of the lower Karroo, and in the High Veld of the Transvaal, about one-fourth, the amount falling as one approaches the coast where the tougher, older rocks are exposed. Judging from the nature of the ground, I would estimate that the denudation in the south-west of Cape Colony at about the same rate as that of the Po region, but in no region of South Africa is the amount anything like the usual rate in Europe as a whole; there the topography is what is called "mature," that is, the land has settled down into a state in which the action of the agents of weathering and erosion is very slow. In South Africa, however, the topography is "immature," the soft rocks are still present, offering enormous fields for the supply of detritus and the combined action of weathering and erosion, or, as it is called, denudation, is extremely rapid.

In addition, the flow of the Karroo rivers is purely flood water; twenty-five years ago the Great Fish River was called

a ten months' river, that is, it flowed ten months in the year. Now, if it flows for one month people are satisfied. In perennial rivers, even those that come down in flood in spring, there is constant work done on the river side by the current, and the valley is kept moist by underground seepage; it is very different in the Karroo, where the whole country becomes absolutely dry with not even a spring in the catchment area.

PART II.

THE CAUSE OF THE DRYING UP.

Chapman's and Livingstone's evidence.—After Oswell, accompanied by Murray, from Colesberg, and Dr. Livingstone had discovered Lake Ngami in 1849, a great number of travellers and hunters went into the country for the purpose of hunting and trade. Of these, James Chapman has left the best account of the district. He was on the Tamalukan in 1853, and through Dr. Livingstone having gone with chief Skeletu on a visit to the northern part of the chief's territory, he missed him, but he received from the doctor a present of a small stock of sago, rice, and other things that might be of use in case of sickness. Andersson had also reached the Lake Ngami from Walvis Bay, and was having trouble, owing to his oxen having been bitten by tsetse fly. Chapman found the Chobe, through the Sunta tributary, flowing into the Tamalukan, and he followed the latter river down to its junction with the Botletle, passing the Tso, which joins the Tamalukan on the south of the Mababe swamps. The water in the Tamalukan was too shallow to float a boat, but its flow was to the south. At times the Chobe and the Tso together came down in flood, and there was a congestion of water in the Mababe swamps, where a lake 20 miles in breadth was formed. "At such times the river is navigable from the lake (Ngami) to Sebetaone's, on the Chobe, and one might travel in a canoe from Chapo's, at the terminus of the Botletle, to the Zambesi."

Livingstone's idea of how the waters were turned northwards, was that a cataclysm of Nature had opened the rent of the Victoria Falls, and drained all the waters into the cleft. It was a favourite expression in early Victorian days, "cataclysm of Nature" and all sorts of things were supposed to have happened through these upheavals. Mr. R. S. Fairbridge, writing with regard to the diversion, says that what caused the diversion was a shallow bar in the river, formed by a storm-carried drift of reeds and brush. "To understand how this was possible, it has to be realised that the watershed between the Zambesi and the Orange Rivers is so flat, west of the Bulawayo-Johannesburg Railway, that when there are heavy rains to the north, the surplus water drains south into the Kalahari, and when there are heavy rains to the south, the surplus runs north into the Zambesi. The long, wide, shallow, reedy depression in which this takes place is called the Tamalukan River, and about three generations ago a very wet season in the north washed a great bank of reeds and rubbish into the southern part of the Tamalukan, where it stuck, and thus prevented any more water draining south towards the Orange River. I have not seen this reed bank myself, but my old friend Swithin Wood, who died in the Old Umtali Hospital in the next bed to me, about twenty years ago, saw it, and told me about it. He was one of the very few white men who has ever been to the spot."

This corresponds with Chapman's account. Chapman trekked from Lake Ngami, down the Botletle to the swamp that was once a lake like Ngami, called Kumado, in which chief Chapo had his town. From here he went on to the Soa Pan. "From the appearance of the banks, which are abrupt and steep, one must suppose that this immense pan must have been at one time a permanent fresh-water lake, for the Bushmen assert that about thirty or forty years ago it never dried up, and abounded with hippopotamus, crocodiles, and fish. But suddenly, they say, the waters from Ngami ceased to flow; the lake dried up, and the dead fish and animals were devoured by vultures."

I have had experience of questioning Bushmen, and can testify to the correctness of their information. They do not lie, and they try to the best of their ability to give the fullest information that their languge will convey. It is a weary process, and takes hours of patient questioning backwards and forwards, and making sure that one's interpreter rightly gives the sense that the Bushmen wish to convey, but in the end the story comes out, and one will always find that it can be corroborated. Now, thirty or forty years before 1854 would give 1820 as a mean date, and this is about the same as Fairbridge's estimate of three generations before 1918. It corresponds, also, with the descriptions of the country before and after 1820; before we find Le Vaillant, Van Reenen, Patterson, Barrow, and Lichtenstein describing the country as being like British East Africa, and directly after 1820 we find Thompson describing terrible droughts, and thereafter we have all travellers telling the same tale with increasing emphasis on the droughts.

I will deal with Livingstone's evidence for the existence of the former Kalahari lakes further on, but I will summarise here his evidence. From Nshokutsa, on the Makoko River, in the south-east of the Ngamiland depression to Andara or Libebe, on the north-west, a distance of about 400 miles and up to the Zambesi, Livingstone found recent lake deposits, full of shells similar in all respects to those living in the Lake Ngami; from this he inferred that at no very distant date the whole of this area had been one vast fresh-water lake. Passarge spent two years in the district surveying for an English syndicate, from 1896-1898, and in every way corroborated Livingstone's evidence, only that instead of showing one single lake, Passarge showed by actual mapping of the lake deposits, that there were two main areas. The one is the Greater Ngami, 300 by 100 miles, on to the floor of which the Okavango and Chobe Rivers spread in deltas. The other is the Makarikari depression in the bottom of which are two pans, the Ntwetwe and Soa; the southern terraces of this depression are clearly defined, and were mapped, but the northern limits are indefinite, being obscured with sand; the area is 15,000 square miles. For comparison I give the areas of the other great lakes in Africa.

Areas of the Great Lakes compared with the former Kalahari Lakes.

	Square miles.		Square miles.
Greater Ngami ...	30,000	Victoria Nyanza ...	26,828
Makarikari...	15,000	Tanganyika..	12,700
Etosha Pan, 20 ft. deep ...	5,000	Nyasa	11,600
Total area of the lost lakes... ...	50,000	Total area...	51,128

The area of the lakes that have dried up in the Kalahari were in area equal to the three largest lakes in Africa, or more than half the area of the five great lakes of North America combined, 93,000 square miles.

It will be of interest here to trace the history of Lake Tanganyika, which has been worked out by J. E. S. Moore and M. Fergusson, because it shows the vicissitudes through which our inland lakes pass. In the beginning, Tanganyika drained into Lake Kivu, and thence into the Albertine Nile, and eventually into Egypt. Within the historic period volcanoes were thrown up north of Kivu, and the waters of Kivu and Tanganyika were cut off from the Nile System; from this time the Nile has been shrinking. From these considerations it would seem probable that after Kivu had filled up through the formation of the M'fumbiro volcanoes, its overplus of water flowed into Tanganyika for a great number of years, until the level of this lake was raised. One of the head-streams of the Congo, then, the Lukuga, worked by head-stream erosion across the watershed, and started draining the lake. It is a remarkable fact that the outlet of Kivu, the Rusisi River, is five or six times the size of the Lukuga; if the Rusisi River were to be cut off from Tanganyika, then the lake would fail to overflow, and would become salt. The water of Tanganyika is even to-day somewhat salt. It seems to be fresher than when Livingstone and

Stanley examined it, while, as both these explorers aver, there are traditions among the Arabs that, in the recollection of living men, it was a lake that had never flowed out at all.

This view of the matter will at once explain the fact that Tanganyika has otherwise unaccountably fallen some forty feet, possibly a great many more feet, within no very great number of years, the overplus of water in it having worn away the channel to the west to such an extent that it will never regain its ancient high level. In other words, the process of draining, which is now complete in the Ngami region, has started in Tanganyika, and is proceeding at a rapid rate. The waters of Nyasa have similarly decreased, but those of Albert Nyanza have increased.

The importance of the central African lakes in the economy of central Africa cannot be exaggerated; without them the region would be a desert. They are large enough to have a circulation system of their own; water is evaporated, falls as rain within their drainage area, and is returned to the lakes and in the process the land is fertilised, streams are kept running, and vegetation is at its best. Contrast North Africa with this part; there we find great mountain ranges in the central Sahara, sufficient to provide that elevation which would induce rainfall if there was any moisture in the air, and yet the land is a desert. Contrast also the Kalahari, the natural prolongation of the central highlands, in which the tropical fauna existed formerly right down to Cape Town, in which, too, there used to be two members of the family of African lakes, and notice what havock the drying up of these has played. In the Congo-Nile divide the consequences of the moisture in the air, due to evaporation from the great lakes is manifest. The south-easterly winds blow the steaming air over to the escarpment, and an enormous precipitation takes place, sufficient to keep alive the densest forest in Africa, the Semliki Forest. The desert, however, is peeping over the tops of the hills, and any diminution of the supply of moisture will result in the advance of the dry lands into the Congo basin; the head streams of the Aruwimi and Welle Rivers will dry up, and

then, first Soudan, and then Saharan conditions will supervene. We are watching the process in active operation in our country. The scheme for dealing with Central Africa is beyond the scope of this work, and I have introduced the matter merely for comparison, and because there are many who say that owing to meteorological and physical conditions, the reconstruction of the Makarikari Lake will do no good.

In Ovamboland the Cunene and Okavango Rivers have built themselves above the level of the flood-plain on either side, and in flood-time the water spills over into a number of channels. The whole country is then subject to what is called the "Efunja," the waters occupy all the lower ground, and half the country is submerged. The natives, the Ovambos, plant their mahonga on hillocks, so that the roots are not totally submerged. From the pools frogs in immense quantities are caught, and serve as delicacies, while in the channels water-lilies grow, and the Ovambos feed on the roots, just as Herodotus describes the Egyptians doing, 2,500 years ago; the water-lily is the ancient lotus (not the lotus of the "Lotus-eaters," which was a berry).

From this swamped area, 70,000 square miles in area, terminating in the Etosha Pan, which used to be a permanent sheet of water, the great rivers that rise in the Angola Highlands were supplied, through the evaporation from the free water-surfaces and from the fields and tropical forests that grew on this great flat plain. The forest was as dense as the Semliki, but it is now dying, and has become invaded with the obnoxious Mopani, a tree that always goes with want of water. I shall deal with the human side of the question later, and it will be sufficient to state that from Tsumeb to Ondongua, a distance of nearly 200 miles, the whole road was strewn with skeletons of Ovambos who had perished in the 1915-16 drought.

The significance of my Ovamboland trip, however, was that I saw desert conditions actually advancing into a tropical country. The Kalahari was invading the area of the headstreams of the Zambesi, Okavango, Chobe, Cunene, and Congo; the source of alimentation of these rivers that supply

a considerable fraction of Africa taken as a whole, was being cut off at the source, with the certainty of the most serious consequences to the welfare of the country. One-half of the Kalahari scheme, the western half, is concerned with remedying this state of affairs, and no one who is acquainted with the country is in any way doubtful as to the expediency of this portion, at anyrate.

South African Meteorology.—The sea is the source of all moisture originally, but precipitations may gather into lakes of sufficient size to establish circulatory systems of their own. Water evaporates from all surfaces of water as long as the air above it is not saturated with moisture; this goes on at all temperatures, even below freezing point, but is more rapid the higher the temperature. If the air is still, the layer of air just above the surface of the water soon becomes saturated, and this gives off its water-vapour slowly to the layers above; in regions of little wind, therefore, in spite of high temperatures, very little water-vapour will be produced. Directly the air is stirred by wind, the lower layer, with its contained moisture, is mixed with the upper, dryer layers, and a new lower layer, hungry for moisture, takes its place. Evaporation is very rapid, therefore, in regions of high and constant winds.

The storm line of the globe is that of the tropics; in the Southern Hemisphere the tropic of Capricorn, 23½ degrees south latitude, runs through the northern Transvaal, north of Pietersburg, through the Kalahari, and through South-West Africa, south of Windhuk; all north of the line is "in the tropics." From this latitude winds blow towards the equator, the south-east trades and on the south of the line, they blow in a westerly direction, the westerly drift.

Owing to the intense heating of the continent, an uprush of air is induced over the interior, and the westerly winds are drawn into a vortex, causing the winds that without this pull would blow from the north-west, to turn round and blow from a southerly direction. This is the origin of the so-called "south-easters" of Cape Town; when there is a depression in the atmosphere, caused by this intense heating,

the air rushes in from all sides. Rain falls in the interior as a consequence of the depression, the temperature falls, and the wind on the west coast returns to the normal north-west. In winter, when this uprush of air does not occur because of the lesser heat received from the sun, the prevailing winds are north-west. Our south-easters, then, owe their existence to what is called in the Indian Ocean, "monsoon" influence. They are not trade winds, since the greater part of South Africa lies below the line of the tropics, within which alone the trade winds can blow.

On the east coast a remarkable phenomenon occurs. East of Madagascar there is a permanent area of depression in the atmosphere, which causes a swirl in the prevailing westerly winds; it is like a wind-devil on a gigantic scale, and always at work. In consequence of this swirl, the air is driven straight on shore in an easterly direction, with most important and happy results for our eastern coastal districts. In passing, it may be of interest to note the consequences of this alteration in the direction of the wind in regard to the animals and plants of our east coast; the westerly drift brings drift wood and seeds to our shores from the west. The best example is the Tristan da Cunha sea-weed that washes up in such quantities round Cape Town. Most of the flotsom, however, from South America passes south of Africa, and is caught in the swirl to the south-east of Madagascar, and is driven on to our east coast. From this cause is due the fact that our east coast fauna and flora has many affinities with the fauna and flora of South America, while the coast nearest to America, the west coast, has few. One example is the South American boa constrictor in Mauritius, that must have come coiled in the trunk of a tree, or the eggs may have been so carried. The "Travellers' Tree," of Madagascar, a South American banana, is another instance, and the examples could be multiplied indefinitely.

This is the position, then:—winds bearing moisture from the ocean, blow on to the land from a north-westerly and southerly direction, on the west and from the east and south-east on the east coast.

As soon as the winds reach the land they encounter high mountains all along the coast, the coastal rampart as I have called it; pressure and temperature are reduced as the air rises, and hence the moisture is precipitated, for air can only hold a limited amount of water-vapour at a certain temperature and pressure; if these are reduced the air drops its vapour as rain. In this way the coastal areas are well supplied with rain, and the hill-slopes facing the sea especially so.

The winds blow inland, they have lost their moisture on the mountains of the coast, and consequently are dry; there is no rain for the interior. South Africa is especially bad in this respect. No other continent exposes such an unbroken line of high coast to the sea, without any notable inlet up which the rain-laden air could reach the interior without having to pay toll of the greater part of its burden. This coastal rampart is continuous right round from Gambia, on the west coast, along the Gold Coast to the Niger, thence south through the Cameroons, across the Congo right down to Cape Town. From here it runs parallel to the south and east coasts up to the Shiré Highlands. Two gaps, however, are breached in it by the Limpopo and Zambesi Rivers, but they are only places which the rivers have hollowed out for themselves, and represent planes that are not so steep as is ordinarily the case; the high level of the plateau is not reached quite so quickly, that is all.

Oceanic Circulation.—It is a necessary consequence of the revolution of the earth, that the water of the ocean, between the continents, on the one hand, between Africa and America, and on the other, between Africa and Australia, should be set circulating in a sense contrary to the directions of the hands of a watch. Between Africa and Australia, the current runs from the Antarctic up the Australian coast, turns west along the equator, and returns southwards down the east coast of Africa. Between Africa and South America, the same circulation makes the currents flow from the Antarctic up the west coast of Africa, across the Atlantic on the equator, and down the east coast of South

America. The currents from the Antarctic are cold, and those from the equator are warm. The continent of Africa has a mean average temperature mid-way between that of the two opposite currents, the warm one on the east, and the cold one on the west. From both sides the air blows from off the sea on to the land, in the one case, on the east, the air will arrive warmer than the land, and in the other case, on the west, it will arrive colder. If the air blows on to the land warmer than the land, it will become chilled, and it will no longer be able to hold the water-vapour that it has absorbed from evaporation over the sea; therefore, rain will fall, and the consequence is that the east coast is well supplied with rain. If the air arrives colder than the land, as on the west coast, then the air warms up, and is not only able to hold its moisture, but craves additional moisture to satisfy its increased power of absorbing water-vapour. On the west of South Africa, therefore, the air arrives saturated with moisture to such an extent that it covers the land with dense fog; the bank of fog over the cold Benguela current, as the cold Antarctic current is called, may be seen from Sea Point, lying about 30 miles out at sea. It strikes the land in Namaqualand, and for days makes all landmarks invisible, the coast being swaddled in a fleecy cloud. Directly this fog drifts inland, the warm land warms it up, the fog disppears, and dry air blows inland. In consequence, on the coast from Namaqualand, through South-West Africa, into Angola, there is along the coast a belt of the most hopeless desert of shifting sand dunes, called the Namib, where the only plants are the extraordinary Narra melon, a sort of bush cucumber, and the still more extraordinary Welwitschia, a fir tree in which the stem does not project above the sand. The land behind the Namib is somewhat better, with a rainfall of up to six inches a year, but it is a desert land compared with the east coast. Similar deserts exist on the west coasts of South America and Australia.

The winds blow moisture inland; most of it is precipitated on the coast ranges, but a remnant accumulates in the interior till the air at certain seasons becomes nearly

saturated. In summer, depressions in the atmosphere come down from the equator. These cause a lessening load on the atmosphere, and the air expands and becomes lighter; on such occasions the air can no longer hold its water-vapour, and the rain falls. On the west coast, the air in summer is noticeably warmer over the land than it is over the cold waters washing up from the south, so that very little moisture is blown inland, whereas on the east, the sea and land are both hot, and the land receives great amounts of water-vapour. The result is that when the depressions from the north come down, the air both on the west and on the east is expanded, but there is no moisutre to drop on the west, but plenty on the east. For these reasons the summer rains fall almost entirely in the eastern districts. In winter the temperature of the land and sea on the west are more nearly alike, moisture in appreciable quantities does blow on to the land, hence, when depressions come along, from the south in winter, they find the land more equally supplied all over; for these reasons the winter rains are more evenly distributed.

It is not necessary to go further into the mechanism of the atmosphere, but from the above outline it is apparent that were there a source of moisture in the country, such as would be given by vast lakes or thousands of square miles of cultivated land, the depressions would more often find the atmosphere at the point of saturation, and rain would fall. It frequently happens at present, that the winds blow up for rain; every sign is favourable, but the clouds disappear, and nothing happens. This must naturally happen, when there are no central lakes, and there is nothing but parched vegetation on the veld, from which no transpiration can be expected. So it happens that the right seasons pass by without the proper rains until there results an accumulation beyond the ordinary, or some more violent atmospheric disturbance wrings out the reluctant rain from the clouds, and a terrific downpour occurs. With the air supplied with reasonable moisture, then every time the conditions are favourable,—and the conditions become favourable in their due seasons—then the rains fall, and are appropriate to the

particular type of country, and the nature of the agriculture practiced in that country, that is to say, the west, would receive copious winter rains and the east summer rains. The Makarikari lake, when constituted, will not of itself start rains; there is no need, for it to be of use, that there should be mountain ranges to precipitate the special water-vapour that is evaporated from it. The moisture from the lake will permeate the whole atmosphere of South Africa, and when the depressions occur, which are determined by movements in the atmosphere of world-wide extent, and are independent of local factors, except to a very small extent, then rain will inevitably fall. The air over the whole of South Africa is exceptionally dry; it requires additional sources of supply, and the natural place to look for this is the lakes that originally gave it.

Mr. C. M. Stewart has advanced the objection that the Great Lakes of North America do not affect the humidity of the air; but, of course, the conditions are entirely different. In North America evaporation balances the rainfall, whereas here it is three times as much. Others, again, have instanced the desert north of the Caspian; here the land is actually below the level of the sea, and the additional barometric pressure which causes the air to retain its moisture, explains the absence of rain. If the objectors, instead of searching the world for evidence against the Kalahari scheme, were to confine themselves to Africa, they would find that all the evidence is in my favour.

I have already dealt with the results of the last of the Kalahari lakes going dry in 1820, and the increasing droughts are due to the last remnants of the former swamps disappearing. The enormous tract in Ovamboland that has practically passed into Kalahari within the last few years, must have an effect on the adjoining country, and the mischief is being felt in Cape Town and the most distant points. There is not a farm in the whole country that has not depreciated in value by the drying up of the lakes, and there is, on the other hand, no place from the coast to the Zambesi, in the provinces of the Cape, Orange River, Transvaal, Natal, Bechuanaland, and South-West Africa,

that will not feel immediately the benefit of an additional water-supply of the magnitude of the Makarikari.

In the last 23 years there have been two good years, the last was 1917. It is more than a coincidence that in that year there were exceptional floods in the Barotse Valley; the water came down in such quantities that it could not escape fast enough over the Victoria Falls, and part of the flood made its way to the Molopo River, and nearly reached the Orange River. The Kalahari was so dry, however, that before the flood reached the Orange River, the bulk of the water became absorbed, and its driving power diminished, so that the water spread out into a vast shallow lake at a place called Abiquas Puts, north of the Orange River. The whole of the Barotse Valley was like an inland sea, and all the swamps were flooded. The effect of this partial reconstruction of the inland lakes was felt throughout South Africa in the good rains that fell. This year, 1919, the Zambesi fell so low that one could nearly walk across the Victoria Falls; there was no inland supply of moisture, and for that reason there resulted the worst drought that is on record. I say the worst, because though the drought of 1861 is said to have been as bad, nevertheless the 1919 drought has come on top of a series of droughts, and the one good year of 1917 was not sufficient to restore the ravages of the previous bad years.

THE AFRICAN RIVER SYSTEM.

If one glances at the map of Africa, one is at once struck by the extraordinary courses of the rivers. The Niger rises in the coastal mountains of the south-western corner of North Africa, goes north-east to Timbuktoo, as if about to run through the desert, then turns right round and enters the sea on the very coast on which it commenced its course. The Congo, likewise, begins by running northwards, then turns a complete semi-circle, and pierces the rampart of mountains on the west coast instead of following the low ground up towards Lake Chad. The Nile is again peculiar

in its course, and the Zambesi and Orange alone seem to run straight from source to mouth like normal rivers of the Amazon or Mississippi type, but these appearances are, as we shall see, deceptive.

Fig. I. Map of Africa, showing the courses of the original rivers.

The second noticeable feature in the African map is the prevalence of deserts like the Sahara and the Kalahari. There is a very widespread misconception of the nature of deserts; the Sahara, for instance, is not a waste of drifting

PLATE I. Lake Ngami, discovered by Oswell, Murray, and Livingstone.
(From a drawing made on the spot (1850) by the late Alfred Ryder, Esq.)

Photo. by] PLATE II. Skeletons of the Ovambos who perished in the 1915-16 famine. [Lieut. C. H. L. Hahn.

sand, as is often imagined, but has an Alpine range of mountains, the Tibesti Highlands, in the centre and on either side are tracts which may be covered with drifting sand, the "Ergs," or they may be just bare stony ground, the "Hammada," or, again, they may be covered with pebbles, when they are called "Serirs." The deserts are, in actual fact seamed by great water-courses or wadys; some of these, like the Igharghar, north of Tasili, can be traced as gorges through the hills and as deep river beds in the flats, though no water now flows down their channels, and in places sand dunes entirely obliterate all traces of them. Prehistoric stone implements for the grinding of corn are found all over the western Sahara, and the ruins of cities of stone-built houses occur, as at Taodeni, north of Timbuktoo, where settled life is no longer possible. River fish of the barbel family are found in pools in the Tasili plateau, far from any river now flowing. All these facts go to prove that the deserts are of recent origin, and were at no very distant date fair portions of the earth's surface, inhabitated by man. Paradoxically enough, the very fact that the desert is over large tracts covered with drifting sand is proof, according to Captain Courbis, of underground moisture, which, by capillary attraction, rises through the sand and binds the grains together; were there no ground moisture the sand would all blow away, as in the stony deserts, or hammada. For the same reasons Foureau considered the Ergs, or areas of drifting sand, to be the broad basis of a former river system.

The deserts and the peculiar courses of the rivers are causally related, and we shall see evidence in the sequel to show that the great African rivers originally ran through the deserts, giving them the requisite moisture to make them normal fertile regions, but that, owing to the diversion of these rivers by others working backwards from the coast and capturing the waters of the inland system, a large portion of the continent has been bereft of its natural supply.

Before we begin the detailed evidence of the capture of the several great rivers, there are a few fundamental facts to be mentioned with regard to the topography of Africa, which perhaps are not generally recognised, but which will

help us considerably in understanding this question of desiccation.

In the first place, Africa is divided into two halves, the line of division being a great volcanic fissure commencing in the Gulf of Guinea by the string of islands, Anobon, St. Thomas, Prince's Island, and Fernando Po. Then inland, there are the volcanic peaks of the Cameroons, Mt. Atlantica, south of Yola, the Marra Hills in Darfur, and the volcanoes in the Bayuda bend of the Nile, between Dongola and Khartoum. The half of Africa north of this line lies for the most part below 1,500 ft. above sea-level, and that south of this line above 1,500 ft.

On the east, from the Zambesi to Abyssinia, there is a great stretch of very high ground traversed by rift-faults of such recent date that they cut across and interrupt the rivers, the courses of which had already been laid down. Here there is a portion of the country to which the ordinary laws of erosion and river development cannot be applied, and we must leave this area out of consideration. Many of the lakes in this area, indeed, have no outlet, and all the drainage from the country adjoining is absorbed in the basins lying in the rift valleys. Lakes Tanganyika and Kivu have been tapped by the Congo and Victoria, Albert, and Albert Edward Nyanzas by the Nile. Lakes Rudolf and Stephanie are drainless and in the south, Lake Nyasa is drained by the Shiré.

In Cape Colony the volcanic lavas of the Drakensberg have been thrown across the drainage from the main watershed of the country, and the upper courses have been turned, and the waters forced across this watershed as the Orange River. The original lower courses of these rivers, the Bashee, Umzimvubu, Umzimkulu, and so on, run impetuously down the steep slopes of the Drakensberg, and straight to the sea. So great is the velocity of the water flowing on such a steep and so short an incline, that the erosion is very intense, and these rivers on the coast side of the Drakensberg are eating back into the mountains, and are in reality trying to restore the original water-parting.

In Abyssinia similar features are exhibited; the short coastal rivers are pitted against the inland ones and these, whether flowing into the Nile or Congo, and so having to traverse the whole length and breadth of the continent, or whether draining into basins without outlet, have far less precipitous courses, and consequently erode or wear down their beds far less rapidly. In far future ages the original water-parting will be restored, but the faulted mass is so broad that at present we cannot recognise the plan as we can in the Drakensberg.

Africa is a great fault-block which has risen recently, speaking in a geological sense, from the sea, much as an iceberg rises when the top burden melts. The continent of Africa is different entirely from the other continents, which have as predominent features folded mountains. The folds, contemporary with the African faults, form, as it were, two concentric ripples round the fault-block of Africa, the nearer ripple being the Alps-Himalayan chain of folds of Europe and Asia and the further ripple being the Aleutian Islands-Rocky Mountains-Andean chain of America. All the waters, then, run from high tablelands, which, owing to the limited time of exposure to the effects of river erosion, have not been carved into the hills and valleys of the more familiar scenery of Europe; the topography is said to be immature. The rivers run in deep gorges separated by wide tablelands, and they flow rapidly to the sea, with water-falls or cateracts in at least some parts of their courses. This vigorous energy of their flow has as a result an intense destructive influence on the beds of the rivers, and erosion is more marked as a trenching or downward cutting effect than as a lateral one, such as we see in Europe, where alluvial valleys are the more characteristic. The amount of sand and gravel carried by a river depends on the energy of the stream, which is measured by its velocity; the sand and gravel dragged along by the river acts as a rasp that wears away the rocks, and hence the greater the velocity the greater is the erosion. The greatest velocity, and consequently the greatest amount of sand and boulders borne by the streams, is at the sources of the streams, where they commence in the hills. This

portion of the rivers is, then, enabled to erode its bed more rapidly than the lower ones, and its action is called **Headstream erosion.** Headstream erosion is the means by which the short, rapid coast streams eat back through the heart of the coastal mountains and tap the waters of the inland system, whose waters are more sluggish. Headstream erosion, again, has tapped the Zambesi basin from the east, and has diverted its waters, which once flowed south-west, through the Kalahari, and has turned it into a desert.

Africa is such a homogeneous mass; its features are so distinctive, different from those of other lands, yet the same in character throughout the length and breadth of its enormous extent, that an illustration taken from one part is an explanation for any other other area. The nature and effect of headstream erosion, then, may be illustrated by a perfect example in Cape Colony, and can be applied to the elucidation of problems in central and northern Africa. This example occurs in the hills south of Grahamstown. A ridge of Carboniferous sandstone forms the edge of a great tableland, 2,500 ft. about sea-level; to the south, the coast-shelf is a thousand feet lower, and the ridge forms, as it were, the hardened edge of a step in a gigantic staircase. On the north, a river scoured a valley in which Grahamstown lies; it flowed east by south, and eventually entered the Great Fish River. The rivers on the south of the ridge, heading in the thousand-feet cliffs of a former sea-coast, have been working vigorously to breach this rampart, and three gaps have been made in it. The first two near Grahamstown, Howieson's Poort and Woest Hill, have simply excavated large basins in the hills, and are every year stealing a little more from the northern drainage-area, with its rivers running in beds with only moderate falls. The third poort, however, is the Blaauw Kranz, where the river has actually pierced the ridge and captured all the eastward-flowing water. The continuation eastwards is the Cap River, which is now beheaded, and its natural head-waters find an outlet through the Blaauw Kranz gorge. The deviation is the effect of head-stream erosion; the fact that a stream flowing eastwards in a natural valley made for it should turn abruptly

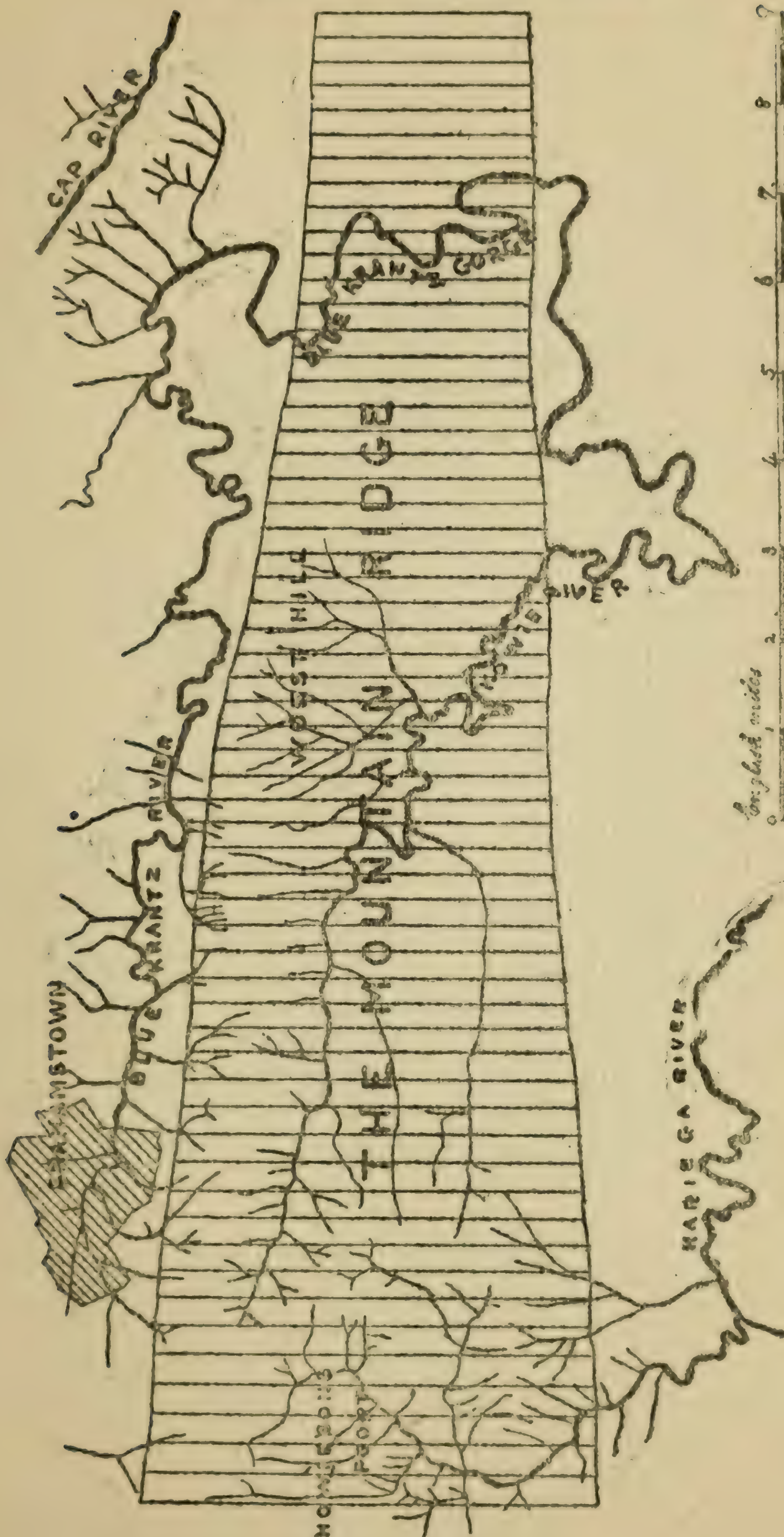

Fig. 2. Head-streams of the Kowie River.

at right angles and pierce a high range of quartzite hills, can have no other explanation, unless we have recourse to faults, of which there is no evidence.

The coastal rampart of hills on the east coast, or on the Gold Coast, is similar to that of the Grahamstown mountain ridge, or Zuurberg. Substitute for the three streams, the Kariega, the Kowie, and the Blaauw Kranz, the Sanaga (Cameroons), the Ogowe, and the Congo, or the Bandama, the Volta and the Niger, and we see on a large scale what has happened on a small scale near Grahamstown; this fact, the capture of the inland water-system by the smaller, but more vigorously-flowing coast streams is the great fundamental fact which explains the alterations going on in the physical conditions all over Africa.

I have referred to the phenomenon of headstream erosion in the Grahamstown hills because I happen to live in that town, and the example is compact and complete, but quite as good examples occur in the western mountains, especially north of Ceres, and generally throughout Cape Colony. In Oudtshoorn there is a further example of two parallel rivers, the Olifants, running in soft Cretaceous rocks, and the Kammanassie, running in comparatively hard Devonian slates. Here we have the conditions represented by the Niger, which flows in Cretaceous strata above the Bussa Falls and its tributary, the Kaduna, which, originally probably of equal extent to the Niger itself, having to erode its bed in hard granite, progressed by feebly, while the Niger spread back and absorbed the whole of the drainage behind the coastal rampart. The Olifants River has similarly spread back and worn for itself a great alluvial plain, while the Kammanassie has lost much of its original drainage area, and lies in a narrow valley.

The topography of Europe, Asia, and Africa was laid down in the Eocene epoch. At the end of the Cretaceous period enormous changes took place; the whole fauna of the world was wiped out, and new forms took their places. Among vertebrates, for instance, the predominant type in the Cretaceous period was that of the reptiles, and in the

Eocene the modern mammalian types were introduced. Africa, which up till then formed one continent with India, was riven by gigantic faults, and the trough of the Indian Ocean was produced. Round this fault-block the continents of Europe and Asia became ranged, with the Alps-Himalayan chain as the backbone. The destruction of life was related to these convulsions in the earth's crust, and we can reconstruct from geological evidence a picture of what then went on. The earth's crust was disturbed, was broken and crumpled, as if a blow had been given it, and the material were plastic like modelling clay. The convulsions were not confined to a single short period, but were spread over what would be regarded historically as an immense stretch of time, and at the end, the world-segments, the continents and oceans emerged more or less in the broad outlines in which we now see them. The movements continued during the Eocene period, and altered somewhat the original plan, but we can regard these as supplementary. As a matter of fact, the barriers raised by these later movements are definitely athwart an earlier topography, and the rivers with which we are chiefly concerned are busy removing them and restoring the earlier features. It is on this assumption that the reasoning in the following pages is based, but it would take us too far from the subject in hand to develop it fully. To put it concisely, the features of the earth's surface, its topography, its rivers, hills, coast-lines, etc, date from the dawn of the modern period, the Eocene; these were on a different plan, and had no relationship to the topography of the earth's surface in earlier periods. That, in the widest sense, is a sort of master-key to the understanding of the present condition of affairs, and the changes that are now going on are alterations of that original Eocene plan.

THE NIGER.

The Niger rises in the granite hills of Tembi Kundu, 2,764 feet above sea-level. These hills form part of the coastal rampart which guards access to the interior from the sea on the Gold Coast, and which, indeed, is a characteristic

feature on the whole west coast as far as Cape Colony. It is deeply canyoned on the sea-ward side towards Sierra Leone and Liberia, and the main watershed has retreated inland under the action of headstream erosion by the short, rapid rivers of the coast. Some of the heights of the original crest, like Mt. Drouple, 9,750 ft., are left isolated, and far south of the watershed.

On the north, the Tankisso River, flowing from the sandstone hills of Futa Jallon, joins the Niger at Siguiri, which is 1,100 ft. above sea-level; thus the Niger has a fall of 1,664 ft. in 260 miles, and the rest of the course of this great river, which amounts to 2,340 miles, has to be accomplished with a fall of a little over two feet to the mile. Further down, the Sankarain River joins the Niger from the south, rising in Mt. Kou, 4,550 ft., part of the Mt. Drouple group. Finally, the two rivers, the Baoulé and the Bagoé, a little further east, rise in the same way, but unite as the Bani River; the latter, after following a course parallel to the main river for some distance, falls into the Debo Swamp. This is the first stage in the capture of the tributaries; the Baoulé and the Bagoé are hesitating in their course, and lose themselves in a level swamp, ready to be deflected. The next river to the east, which rises in the same way from the coastal rampart, is the Black Volta; this flows northwards as the others do, but a coastal stream still further east has eaten back through the rampart, stolen the waters of the northwards-flowing stream, and this in turn has captured the waters of the Black Volta, uniting thus three original rivers in one great stream. A small tributary from the north, flowing into the Volta at the bend, marks the former course of the stream into the Niger.* This precisely is the history of the Niger itself, carried out on a smaller scale. The other branch of the Volta, the White Volta, does not show this diversion so clearly; its headstreams penetrate nearly to the Hombori Mountains, in the bend of the Niger,

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* Attention was first drawn to this capture by R. de Lamothe, in "Contribution à l'étude geologique des territoires du Haut Senegal-Niger." Bull. Soc. geol. Fr., (4) IX., 1909, p. 528.

and a string of lakes on the north of the mountains lie in depressions, which probably mark the course of the river before its waters were captured and brought south.

All the tributaries east of the Bagoé have been reft from the Niger, and a very little further erosion by the Bandama River will bring the waters of the Bagoé southwards. Then the Baoulé will form a bend similar to that of the Black Volta. Its waters will flow southwards along the drained channel of the Bagoé, and will reach the sea at Grand Lahou by the Bandama River. The Bani, now forming the common conduit for the Baoulé and the Bagoé, will then gradually silt up and all connection with the Niger will be lost. We shall see later, in connection with the Benué and Cunene Rivers, that some African rivers are just in this stage when the waters are hesitating as to which way they shall run, and the river with the shorter course always wins in the end, draining the area and leaving the bigger river without its natural tributaries.

Not only has the Niger lost the waters of the White and Black Voltas, but, nearer its course the Senegal River has invaded the drainage area of the river and in the tributaries, the Bafing, the Bakoy, and another river of the name Baoulé, we see clearly by their courses that they once belonged to the larger river. The Senegal River originally began in the Tamboura Mountains, near Bafoulabe, but the short, straight course, combined with the easily-weathered, horizontal sandstones of this area, allowed it to eat into and rob the Niger of a considerable portion of its waters. As it is, the Senegal River is steadily gaining ground in the natural basin of the Tankisso, and at some future date this great tributary of the Niger will be lost to it.

The floods of the Niger extended more than a hundred miles north of Timbuktoo within the memory of man, but these inundations are far more restricted nowadays; this is usually ascribed to the drying up of the continent, but it is far more probably due to the fact that ever year sees many square miles of country, which formerly contributed its waters to the Niger, drained by the encroaching coastal

rivers. The Senegal is the chief thief on the west and on the south, there are the Liberian rivers, the Sassandra, the Bandama and the Comoe. Thus, waters which originally went to fertilise the inland districts, are now drained rapidly to the sea, and their beneficial effects are lost.

Some 300 miles above Timbuktoo, the Nigers enters a great level plain, which is liable to inundations, the waters at such times forming a lake 170 miles long and 80 miles broad. At ordinary times the waters are restricted to a reticulating system of channels, and one more or less permanent lake, Lake Debo. A further system of shallow depressions extends northwards, west of Timbuktoo, the largest being Lake Faguibine and Lake Horo. All the wells dug north of Timbuktoo as far as Arouan, 200 miles north of the Niger, are in fluviatile deposits, full of shells of *Melania*, *Physis* and *Planorbis*, showing the former extension of the flood-lake system. A vast region like this, with practically no fall, indicates a temporary phase in the evolution of a river system; the Niger below the Debo Swamp has not cleared its course sufficiently to accommodate itself to the new conditions.

With reference to Lake Faguibine, Mr. H. S. W. Edwardes, District Officer at Sokoto, Nigeria, writes:—"In the Sokoto Province of Nigeria I found lake formation associated with desiccation in the following manner. Tributaries of the Sokoto River which have ceased to flow have had their mouths closed by detritus brought down by the flood of the river, which, in raising its own bed, has barred their valleys. The resulting lake was fed each year by the flood water from the river, and the sediment dropped when the water lost its velocity in the backwater round the bar. At Gaudi, where Lake Kubiri provides a very clear example, the bar is 16 feet above what must have been the original valley-bottom. The lake was perfectly dry, owing to the failure of the Sokoto River for many years to reach the level of the bar it had constructed when its water-supply was more abundant. I cut a canal about 1,200 yards long from a point up-stream, and the lake is now 11 miles long, and contains 12 million cubic yards of water. Half a dozen dry depressions due to

the same natural causes were dealt with in the same way, with the result that lakes containing over 20 million cubic yards, and covering nearly 3,000 acres now stand there. Many other examples remain to be dealt with in due course, and the benefit to the people in this semi-arid region is out of all proportion to the absurdly small cost of the work required. From observations it appears that during the eight months of the dry season about 4 feet of water is taken from the lakes by evaporation and soakage, both processes of value to the vegetation in the vicinity. Thus, from every acre of water over 4 feet deep some 6,050 cubic yards are used up annually. If the lake is able to refill itself at high river this forms the annual profit, the water saved from the sea each year for local use. Of course the direct benefits to the people for fishing and irrigation are immense, but the factor of evaporation is a very real asset. The conditions in the Timbuktoo area are on a much bigger scale, and the benefits to be derived from their improvement correspondingly great. Faguibine and its adjoining lakes appear to have an area of about 500 square miles. The annual evaporation from this would be about 2,000 millions cubic yards—well worth saving from the sea. A short study of the large-scale maps made by the French of Timbuktoo suggests that the collection of lakes in the vicinity may be due to similar causes, the flood-water of the Niger having brought down masses of detritus from the hills, where it rises and spreads over the plain, raising the river-bed, blocking valleys and creating depressions. It would seem of the utmost importance that the storage of the Niger flood-waters in these lakes should be facilitated in every way."

This remarkable confirmation of my views from West Africa is important, as it establishes what I have always maintained, namely that, from a physiographic point of view, Africa is a continent self-contained, and similar in all parts. The building up of the rivers above their plains and making a sort of raised canal for themselves, is, however, common to many semi-desert regions of the globe. On the Murray River, in Australia, for instance, this process is in active operation; the lakes formed from the overflowing of

the banks during floods are called "Billabongs." An inspection of the map of Ovamboland shows these billabongs very well on the Cunene River, on the side towards the hills; the side away from them allows the free flow of water, and the spill-ways, or oshanas as they are locally called, lead out from the raised river-channels.

At one time it was thought that round about Timbuktoo there had been an inland sea like the Black Sea, which communicated with the Atlantic through a channed in the Adrar Highlands; Chudeau even designated this channel as the depression El Khat (lat. 19° N.). According to Lemoine, however, all the evidence for such a sea lies solely in the presence of countless shells of *Marginella,* which are found strewn about in the soil round Timbuktoo. These sea-shells were at one time used as money, and were probably the "cowries" which poor Mungo Park was presented with by the Sultan of Segu; Park estimated his present of 5,000 as being worth about twenty shillings. The cheapness and profusion of these shells would lead to the improvident natives dropping quantities of them, and hence their presence round the city can be explained.

The great salt desert of El Juf, with the salt mines at Taodeni on the eastern margin, is the relic of a dried-up lake rather than that of a sea, and further, the levels of Timbuktoo (787 ft.) and Taodeni (722 ft.) rules out this theory, unless we bring in movements of the earth's crust, which can only be purely speculative. To the north of El Juf there are the Ergs, regions of shifting sand-dunes, which are, according to Foureau, the broad basins of a quaternary river system. It has now vanished, but it once led north into the great Igharghar and thence to the sea by the shotts, or lagoons, of Algeria. Just south of Taodeni, Lenz marks a depression only 400-500 ft. (120-150 m.) above sea-level, inviting the waters of the Niger to flow into it, and to form a great central Saharan lake.* Further north, there are the oases

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* See Lieut. Cortier's route march from Timbuktoo to Taodeni, "La Geographie," 1906, pp. 317-341.

of Twat, Gourara and Wargla on the line of such a supposed river. Compartively high ground lies between Gourara and Wargla, but the whole of this area is covered with enormous thicknesses of recent debris, washed down from the Atlas Mountains; this would obscure any pre-existing river valley, and would also have aided in the obstruction and final diversion of the stream.

There is another possible outlet for this river system, namely, through the Adrar Highlands, bordering the west coast. At Cape Blanco there is a great estuary, between four and five miles broad, now filled in with light, friable sandstones, that could have been the mouth of this river. This, however, would not have given the requisite moisture to the Ahaggar Mountains, and allowed them to pour plentiful rivulets out into the present deserts, which, joined together, scoured the great river-beds we find in these regions; the larger ones, such as the Tanegrouf, In Azoua and Tafassasset are now, indeed, dry, but at one time they were filled with water and communicated with the sea. In the heart of the Ahaggar, in the pools, there still live the river fish, *Barbus deserti* and *B. biscarensis,* which must have originally swam up a river that flowed far from their present haunts. These central Saharan highlands are so hemmed in on all sides by vast plains, separating them from the coastal regions, that no climatic changes would suffice to bring rain-laden clouds in such quantities as to allow of their giving rise to great rivers that could flow the 1,200-1,500 miles to the coast, unless the plains around them were moist with an irrigation brought there from more favoured regions.

On the north of the Ahaggar massif, which is of granite, (Mt. Hamane, 7,150 ft.), the great Igharghar waddy cuts first a deep canyon through the Tasili, or plateau, of the Ajer, consisting of Devonian and Carboniferous rocks, and then becomes lost under the great Erg, or region of shifting dunes. On the north of the Erg, the waddy reappears, and its course is marked by wells and irrigation works, showing the presence of abundant underground water. It seemed possible at one time, that the Lake Chad might have discharged its waters northwards, and through a rift in the

Ahaggar highlands, have led down into the Igharghar, but the documents of the Foureau-Lamy mission are so definite as to the great escarpment facing south and barring all drainage from south to north, that one had to abandon the idea.

To come back to the Niger, the river, after leaving the neighbourhood of Timbuktoo, enters the Burrum Gorge, flowing in it due east for 250 miles in a trench scarcely 300 feet wide. Thence it follows along the junction of granite on the south-west and soft Cretaceous and Eocene rocks on the north-east, until it reaches the Falls of Bussa, where Mungo Park perished. Here the granite stretches across the river in a comparatively narrow bar, and forms, on the east, the continuation of the coastal rampart, which rises near Bauchi to 6,400 feet. The Niger in this region consists of two branches, the Niger proper, and the Kaduna River. Both originally rose in the coastal rampart. The Kaduna has eaten back by headstream erosion, but its upper tributaries draining a compact granite area, and having only hard rock to work on, has not progressed far into the interior; the Niger, on the other hand, having only a narrow bar of hard rock to eat back through, and behind that the soft rocks of the Cretaceous and Eocene formations, has tapped the whole of the drainage area behind the coastal rampart. The course of the Niger between Timbuktoo and the Bussa Falls, was once a river rising on the north of the coastal rampart and flowing north-east. The region of dead water in the Debo Swamp indicates where the two northwards-flowing rivers originally met.

The stages in the erosion of the rivers of the Gold Coast are so complete in their varying degrees of breaching the coastal rampart, and the action is so similar, on a large scale, to what is found going on in so many of the rivers of Africa, like in the Kowie, that one is justified in drawing the conclusion that the Niger once flowed into the Sahara, and made it a habitable region. The fact that has enabled the Niger to work this act of spoliation is the sudden thinning of the bar of hard rock at Bussa, which elsewhere

guards the drainage of the interior and the presence, behind it, of soft uncompacted strata.

The future development of the Niger region is full of disaster for North Africa. The Volta has completed its spoliation; the Bandama is busy stealing the Bagoé and Baolé tributaries; the vigorous headstreams in Sierra Leone and Liberia are eating into the area of the upper Niger, and sometime in the future this will drain to the sea by the St. Paul or the Moa River; the Senegal River is stealing into the basin of the Tankisso River. Thus, the ultimate evolution of the south-west Sahara, will result in an absolutely waterless desert. Not one of its present streams, whose waters reach the sea by such a long route, can compete with the boring headstreams of the coastal rivers. The only thing that would prevent the fulfilment of this would be a bodily tilting of the whole continent, and such readjustments, due to the lightening of the earth's crust by the mass of rock weathered away and carried to the sea by the rivers, and also, by the absence of tons of ground-water that now permeates the soil, have taken place in the past, and may do so again in the future.

For the geology of this portion of Africa I have used the work of P. Lemoine, in Steinmann and Wilken's "Handbuch der Regionalen Geologie," and for the topography, geology and archœology of the central Sahara, the volumes of the "Mission Foureau-Lamy," Paris, 1905.

THE BENUÉ.

This great tributary of the Niger is, at its confluence, a larger river than the main stream; it comes fresh from the Adamawa Highlands and the coastal rampart hills, whereas the waters of the Niger have come a very long way, and have visited the outskirts of the Sahara. The Benué, in the orginal plan, began in the coastal rampart, or escarpment, through which it has now cut back. The physiography of the country immediately adjoining the stream is very char-

acteristic. Above Yola, where it occupies a river-bed, in which the waters formerly flowed towards Lake Chad, instead of away from it, there is the same deep, narrow channel that we saw in the Niger, below Timbuktoo, and which we shall see again below Stanley Pool, on the Congo, and in the Kebrabasa Falls, on the Zambesi. Below Yola, where headstream erosion had been in play, the coastal rampart appears as two great ranges bounding the valley, at some places approaching, at others retiring some distance from the river. It is very instructive to compare this river gorge with that in which the Congo flows below Stanley Pool; here, the Congo flows in a steeply inclined river-bed, interrupted by continual rapids; whereas the Benué, breaching the same rampart, is navigable throughout, with a fall of only one foot in the mile. In other words, the cutting of this breach, in the case of the Congo, is of much more recent date than in the case of the Benué. This leads one to the question of what happened to the waters of the Congo before the breach was made? The answer is that it flowed north to Lake Chad, but I shall develop the evidence for this later.

The Benué has had, however, long ages of thieving to its credit, and its tributaries are everywhere stealing into the basin of Lake Chad. Captain Lenfant, starting from Garua, on the Benué, ascended the river in a small boat, the "Benoit-Garnier," drawing two feet of water; by following the Moakebi River, he actually reached the Tuburi Swamps, and thence descending the Logone River, he reached Lake Chad. At Binderé Moundang he had to take the boat to pieces and carry it for twenty miles, before reaching the Tuburi Swamps. The whole of this Tuburi region is one of hesitating flow, like round the Etosha Pan, that is still connected with the Cunene River in flood time; a deserted river-bed to the south of the present one, connects the Kebi River with the Tuburi Swamp. To the north and south of the upper Benué, tributaries can be seen on the map interdigitating with the Chad affluents; it is only a question of time before the whole system of rivers flowing into Lake Chad will be captured by the Benué and diverted to the

Photo. by] [R. Schlange, Tsumeb

PLATE III. The Ovambo River in flood, showing absence of current, Ondera.

PLATE IV. The Etosha Pan, eastern edge.

The White Sand of the Omaheke.

Ondonga women wearing aprons of ostrich-shell beads.

Atlantic. The robbery is actually proceeding under the eyes of living men; Lake Chad is yearly becoming less extensive, and the desert sands are filling it up. We can, then, compare the Logone and Shari Rivers, which are in the course of being diverted to the Benué, to, say, the Kasai and the upper Congo, which have actually been diverted to the Atlantic. The direction these rivers take is the same; a direct northerly run, then west, and then south. The whole of the Congo drainage, the whole of the Lake Chad drainage, once poured north into the Sahara; first the Congo portion was filched, and next the Chad portion is going.

THE CONGO.

The plan of the Congo River, as it exists at present, is surely the most puzzling of any river system in the world. There are three sections. The first is the section from the Kwango River to the Sankuru River, where some twenty great rivers flow from the highlands of north Angola, in almost straight courses, due north, and then are collected by a river flowing due west. Two of the northward-flowing rivers, the Lomami and Lualaba, further east, have not been tapped by the westwards-flowing river, but continue their northward course for another three hundred miles, till the Aruwimi River, flowing west, cuts them off; this is the second section. The third section is the Ubangui-Welle River, which flows west from the mountains about Albert Nyanza, and then turns south. All the water poured forth by these great rivers ponds up against the coastal rampart, and forms the Stanley Pool, from which it flows over a series of cataracts to the sea. On the northern bank of the Ubangui River rise the tributaries flowing into Lake Chad; the Gribingi and Fufa Rivers actually rise some seventy miles north of the Ubangui. The watershed between the Gribingi and the Ubangui is about 400 feet high above the Ubangui stream-level. Just at the bend of the Ubangui, the Tomi River has a course similar to that of the Black

Volta; it rises in the hills, about 50 miles north of the Ubangui, flows north towards Lake Chad, and then makes a complete semi-circle and flows south into the Ubangui. This shows that the rivers are more vigorous on the south of the divide than on the north. The opening of the poort through the coastal rampart, to let through the waters of the Congo, is fairly recent, but it has allowed the rivers to scour their valleys very considerably, and a scour of 400 feet is not a very large one to assume. In Cape Colony, in the Eastern Province, and the Transkei we see valleys which have cut deep, narrow canyons four times as deep. Raise the level of the rock-barrier at Stanley Pool, and the whole water-system behind will be checked; if the elevation be sufficient, the whole drainage of the Congo would pour into Lake Chad. The following are the heights above sea-level:—

In the bend of the Ubangui, Zongo...	1287 feet	
,, ,, ,, Banzyville	1384 ,,	
Mouth of Tomi River (about) ...	1335 ,,	Difference 485 feet
Highest point in the Ubangui-Gribingi divide	1820 ,,	
Stanley Pool	923 ,,	897 ,,

In other words, it requires an elevation of 485 feet at the mouth of the Tomi River to empty the Ubangui River into Lake Chad, and an elevation of 897 feet at Stanley Pool to empty the whole of the Congo waters into Lake Chad.

There is a poort in the Zwartberg Mountains in Cape Colony, called Meiring's Poort, in which the mountains rise to 7,000 feet above sea-level, while the level of the river is 1,000-1,200 feet, giving a depth of a river-cut gorge of 5,800-6,000 feet. Throughout the coastal mountains of Cape Colony there are similar poorts cut by the rivers since the Cretaceous period, and there is nothing, therefore, to stop one assuming that a river of the volume of the Congo in flood may have cut down some 900 feet in comparatively recent times.

The whole plan of the river system on the inside of the coastal rampart shows that the barrier existed quite recently,

and that the rivers have not yet had time to adjust their beds to the changed direction of flow. The Kwango River and all the northwards-flowing rivers, as far as the Sankuru River, now deliver their waters to the Congo by the Kwa River, but the first ten or a dozen apparently gathered together and ran north through the Leopold II. Lake and Lake Tumba; from here, northwards, along the valley of the Ubangui River, and thence down the Gribingi River to the Shari River, and so to Lake Chad. The next eight or so of the northwards-flowing rivers originally took a similar course, but all trace of them has been lost in the great plain in the embrace of the horse-shoe of the Congo; this area is now drained by rivers flowing west, and whicht rise quite abnormally close to the left bank of the Lomami River. The next two rivers, the Lomami and the Lualaba, maintain a northerly course for a greater distance before being deflected westwards; their original courses were, probably, across the flat divide, between the Congo and the Ubangui River, which is some 120 feet above the level of the main stream, and found an outlet into the Ubangui River somewhere near where the Welle River now enters that river. The progressive stages of the deflection of the northwards-flowing rivers, as one passes eastwards, is very instructive; near the breach in the coastal rampart, the rivers have been drawn closely in, and as one goes further away the westerly drag becomes less and less felt. The whole horse-shoe of the Congo, from Stanley Falls (1,391 feet) to Stanley Pool (923 feet) has a fall of 478 feet; as the distance is quite 1,000 miles, this gives an average fall of less than half a foot in the mile. Lake Chad is 81 feet lower than Stanley Pool, but from Stanley Falls it is 200 miles further, so there is a nice balance between the two outlets. To appreciate this, one must obliterate all valleys as they now exist, and think of the country as an inclined, featureless plain; we then see that the rivers, were they free to flow without their present confining banks, would have very little choice between Stanley Pool and Lake Chad; in practice, however, the more vigorous coastal streams always prevail over the more encumbered ones of the interior.

Stanley Pool has absorbed the Congo drainage for a very long time, but the sluggishness of the river above the Pool, shows that the capture has not been so very remote. The horse-shoe of the Congo represents the bend of the Niger above the Bussa Falls, but the original outlet to the north is not so clearly marked in the case of the Congo as it is in the case of the Niger at Timbuktoo.

The crest of the coastal rampart is a range of hills, nearly half-way between Stanley Pool and the head of the estuary, at Matadi, culminating in Mt. Ulia, 3,430 feet. From this ridge the Congo originally flowed west to the sea, like the rivers to the north, the Chiloango, the Niari Quilo, the Nyanga and others. The next great river to the north, however, the Ogowe, has eaten back through the coastal rampart, and is making a bid for the inner drainage of the continent. With two rivers equally vigorous, tapping the same source, the river traversing the softer rocks wins. The escarpment rises to 4,500 feet at Mt. Otombi, where the Ogowe traverses it, as against 3,430 feet, the highest part of the rampart that the Congo has to breach. Generally, with this coastal rampart, it may be taken that the higher the peaks, the more massive and more resistant to the agencies of weathering they are.

There is an interesting example of complicated river capture in the Dscha tributary of the Sanga, a large river that enters the Congo, just below the Ubangui confluence. It rises in the south of the Cameroons and flows westwards, as if to join a coast stream, the Nyong River, which is just south of the Sanaga River. This Nyong River pierced the coastal rampart, and was stealing the waters of the interior, when the great thief, the Congo, seized the prize, and the Dscha now turns round in a semi-circle and flows eastwards. Tributaries of the two rivers, the Sso of the Nyong, and the Lobo of the Dscha, come very close to one another. The struggle for territory is very keen in this area. The affluents of Lake Chad, the original owners, are steadily retreating northwards, as the Sanaga and other coast

streams invade their basins. The Congo in turn, through its western affluents, bringing every year more force to the head streams as the lower river becomes cleared, is steadily filching from the Lake Chad area and the conquered territory of the coast streams.

RIVER CAPTURE IN THE CAMEROONS.

Fig. 3.
The Nyong and Dscha rise from the coastal rampart.

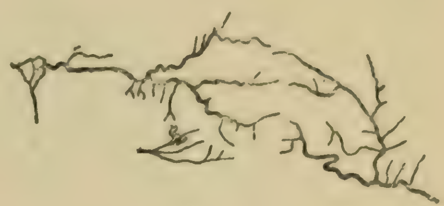

Fig. 4.
The Nyong eats back by head-stream erosion.

Fig. 5. Present state; the Dscha has recaptured two of the head-streams.

LAKE CHAD.

Lake Chad lies 842 feet above sea-level. It is a sheet of water that is rapidly diminishing from the filching away of areas originally draining into it, by more vigorous streams from the west and south. It is not a lake in the ordinary sense of the word, with well defined basin, but falls into the

category in which are Lake Ngami, the Etosha Pan, Lake Leopold II., Lakes Debo and Faguibine on the Niger, and the Bahr-el-Ghazal on the Nile. That is to say, Lake Chad is part of a river system that has been blocked up, and is evidence of the diversion of the general drainage of the country, which is in the act of being consummated.

On the west, the natural boundaries of the Lake Chad drainage area is the coastal rampart in the Cameroons and Nigeria; this is continued into the Sahara, through the highlands of Air, or Asben, up to the Tasili, or Plateau, of Ajer. From this side only two affluents now reach the lake, the Kamerduga Yobe, from the direction of Kano and the Jedseram, to the south. The Benué thrusts itself boldly into the south-western drainage area, and on the north-west the Saharan highlands have now no moisture to contribute to waters of the lake. There is, however, an oasis in the desert, east of Air, called Agram, which owes its existence to the underground moisture. These oases, as one learns from the Igharghar, are on the courses of dried up-streams, and the underground rivers are relics of former streams that flowed above ground. On the south, the Logone affluent is being filched by the Benué, through the Tuburi Swamps, and there remains only the Shari River, with its many tributaries, as a constant and settled contributor.

On the east there is the Bahr-el-Ghazal, which has nothing to do with the Nilotic river of that name. The eastern boundary of the Chad basin is formed by the Tibesti Highlands and the Ennedi Hills; one would expect these to drain towards the lake. One finds, however, that at the foot of the Tibesti Highlands there are places, visited by Nachtigal, which are 350 feet below the level of Lake Chad. This is evidence that the waters of Lake Chad are held up by silt and sand above the normal height, and explains the expansion of the river into a lake; it also shows that this river system once flowed from the lake towards the Tibesti Highlands, in an easterly direction. The whole system of wadys on the western side of the Tibesti Highlands is collected by larger wadys directed towards the south-east; that is to say, when there was sufficient water to fill these

Fig. 6. Map of the Chad Region.

wadys, it did not flow towards Lake Chad, but turned round southwards and made for a gap in the Ennedi Hills. The inclination of the Bahr-el-Ghazal is in the same sense,

eastwards. The Bodelé and the Djourab are districts lying under the Ennedi Hills, at the eastern end of the Bahr-el-Ghazal, with a general level of some 200 to 300 feet below that of Lake Chad. According to the geological map of this region, by Captain Arnaud, the depression of the Bahr-el-Ghazal, lies within a semi-circle of high granite hills, Tibesti on the north and a series of heights to the south, about Wadai; these connect with the granite of the coastal rampart. The Shari and Logone Rivers pass through a gap in the granite hills. Between the Tibesti massif and the southern one, there is a gap in the Ennedi Hills, which are composed of horizontal sandstones, such as Foureau has made us familiar with in the Tasili, or Plateau, of Ajer, which lies to the north-west. Foureau found this latter breached by a vast canyon, in which the Igharghar once flowed from the watershed on the south. The expedition of Captain Arnaud visited the southern end of the Ennedi Hills, and no outlet was observed through the escarpment. Such an outlet may exist, although it may not be visible from a distance. Many of the deepest poorts cutting the coastal mountains of Cape Colony, like Meiring's Poort, cannot be identified from a distance, nor would a way through the mountains be suspected by anyone approaching to within even a few miles of the poorts.

It is the general rule among geographers to make the Tasili-Tibesti-Marra Hills line a great water divide for this part of Africa, but there is no real reason for maintaining this. I would rather divide North Africa into three partitions, served by three northwards-flowing rivers, the Proto-Niger, the Photo-Congo, and the Proto-Nile.

Besides the fact that the gradient of the rivers is inclined from Lake Chad towards the Ennedi Hills, which is similar to the case of Lake Faguibine on the Niger, with the depression near Taodeni, three hundred feet below the level of the lake, there is a further parallel between the Niger and the Chad systems. At Taodeni there are vast deposits of rock-salt, filling in synclines of the older rocks, and often outcropping on the surface. To the east of the Djourab depression, on the other, that is, the east side of the Ennedi

Hills, there are the sale mines of Domi. In the case of Taodeni, we ascribed the salt deposits to the drying up of an inland lake, like the Great Salt Lake of Utah; the same applies to the salt deposits of Domi. The water to fill such a lake must have come from the Lake Chad direction, for the Tibesti Highlands could never of themselves have afforded sufficient moisture to fill it, seeing that they are entirely isolated by immense stretches of desert. Further, we find east and north of Tibesti the great depression of the Libyan Desert, filled with shifting sand-dunes; there is still abundant underground moisture, however, which comes to the surface in the Kufra Oases, and further north in the Oasis of Augila.

The Tibesti Highlands culminate in the volcanic peak of Tusidde and Emi Kussi. Nachtigal found the valleys on both sides of the range with flowing water, and with apes, gazelles and birds to enliven the scenery. The moisture to maintain this state of affairs is drawn from the depressions of the Djourab, Bodelé and Chad, and is precipitated by the cold surface of the high peaks of the Tibesti range. The rivers now disappear in the sand at the foot of the hills, and what we now see in the shape of animal and plant life is a relic of a time when the whole district was not only much more moist, but was connected by fertile plains with the rest of the habitable part of Africa.

Col. Tilho, who has recently returned from the district, states that as far as he was able to see, the slope of the country at the foot of the Ennedi Hills was towards Lake Chad, and not eastwards. In other words, the Chad basin is a closed one, and is not open towards the Nile; the basin reached its lowest elevation in what Col. Tilho calls the Chad Lowlands. This and the discovery of beds of lake shells, skeletons of fish, etc., led him to the conclusion that all this region was once occupied by a vast expanse of lakes and marshes, comparable to the Caspian in size, and possibly identical with the famous Chelonides of ancient geographers. Col. Tilho ascended the Emi Kussi volcano, and found it to be 11,200 feet; within the crater there is a vast pit, 2 miles in diameter and 1,000 feet deep, with a deposit of carbonate

of soda at the bottom. I personally believe that this or the neighbouring Mt. Tusidde (7,800 ft.) is the Mount Atlantica of Herodotus, which commentators usually identify with the Peak of Teneriffe; the Nasamonians who made the journey to the south, came to a river running east, the Bahr-el-Ghazal, and were taken by the pigmy inhabitants to one of their towns. This river is identified by the commentators as the Niger, but pigmies never came near this river; it is essentially a negro country. The whole of the geography of Africa given in Herodotus, requires revising in the light of the recent explorations of the Sahara. Dr. Falconer admits an outlet of the Chad basin to the east, but denies that the Congo ever drained into it; my explanation gives the reason for Col. Tilho's Saharan Caspian, which would require a mighty river to keep it supplied, and we must wait for a survey of the country before we can rule out the possibility of an eastern outlet. Once through the gap, the course of the Proto-Congo would lie past the oases of Kufra, which covers 7,000 square miles of fertile ground in the centre of the Libyan Desert; thence to Augila, and so out to sea in the Gulf of the Great Syrtis.

On the west of Augila, there is a valley, between the Tasili of the Ajer on the south, and the Black Hills on the north, in which lies the great oasis of the Fezzan. It is a very large, fertile district, with vast dry river courses directed towards our supposed former river, as if to join it as tributaries. Here, again, we have evidence of a former much more plentiful rainfall.

At Augila there is a great wady, the Bessame-Schecherre, which is in the form of a horse-shoe, with the rounded end pointing south. This rounded end would have received our supposed Proto-Congo; the eastern portion was connected with the Nile through the Oasis of Siwa and Bahr-bila-ma, while the western branch led to the sea. At one time it was thought that the Augila Oasis, together with the depressions to the east, formed an arm of the Mediterranean; this theory was due to a wrong estimation of the height of Augila above sea-level. Rolfs first put this height as 100 feet below, but later measurements have fixed it at

130 feet above the Mediterranean level. From this supposed inland sea, the great fertility of the Fezzan, in early historic times, was thought to be due; this, however, would be far more naturally explained by the fact of the Congo waters flowing through the desert and fertilising the neighbouring lands, as one river, the Nile, still fortunately does. On the coast, north of Augila, is the Barka Plateau, the Garden of Hesperides of the ancients, where about 600 B.C. flourished five cities of the most astonishing luxuriance—Cyrene, Apollonia, Arsinoe, Berenice, and Barke (Ptelomais), constituting the Pentapolis of Cyrenaica. One can picture the condition of things in those times. The great river passing the Tibesti Highlands, which, precipitating the moisture drawn from the fertile valleys at their base, sent many tributaries to join it; from here to the sea, a well-watered land, with pastures stretching eastwards till they united with those along the Nile and on the west, the whole of the Fezzan a continuous tract of luxuriant vegetation. All the wealth of this back country reached the cities of Cyrenaica, which attained an opulence quite unexplainable on other grounds. Then the coastal river, far to the south, eating back through the coastal rampart, tapped the head-streams, and century by century captured more waters, till the whole of the Congo drainage was diverted; the head of the river system then began where the Gribingi now does. Then the Benué, eating inland, captured a great part of the effective drainage area still left. The river flood was no longer able to surmount the barrier of the Ennedi Hills, and the fair country along the river, of which a sample can still be seen in the Oases of Kufra, became

> " A region of emptiness, howling and drear,
> Which man hath abandoned, from famine and fear."

Sir Harry Johnston writes that this theory, at first startling, finds great support from recent French investigations in the Sahara, and from British and Italian explorations in the Libyan Desert. For instance, the enormous quantities of hippopotamus bones and tusks found in the central Sahara show that that region at no very distant time must have been dotted with lakes and seamed with rivers.

The filching of the drainage areas by the Benué is still going on, and is reacting on the Libyan Desert to its disadvantages by lessening the flow of underground water. How recent these changes are, can be realised by the fact that when Rolfs in 1874 set out from the Dakhel Oasis in Egypt to cross the desert to Kufra, by a track that had been in use from time immemorial, he found that dunes had risen across the route to such an extent, that it was no longer a practicable course.

Lake Chad has been instanced as a case where a large body of water does not result in general fertility of the surrounding region, with the inference that similarly, if my plan of recreating the Kalahari Lakes were to be carried out, there would be no effect on the country. It is all a matter of proportion. The Orange River exposes too small a surface of water to affect beneficially the surrounding country; the proportion of water to parched land is 1 to 10,000. In my Kalahari scheme I obtain an evaporating surface one-tenth of the area deficient in moisture, which is a proportion big enough to make an impression. In the case of Lake Chad, the area of the eastern and western Sahara is so vast that all the water evaporated from the lake would yield less than half an inch of rain a year; before the lake was deprived of its main affluents,its area was fifty times its present size, and a rainfall of 25 inches of rain over the Sahara would make a difference.

THE NILE.

Of the three great rivers which flowed north and fertilised North Africa in ancient times, only one remains, the Nile. Owing to recent volcanic eruptions north of Lake Kivu, the drainage area of Tanganyika and Kivu has been cut off from the Nile, but before this happened, the northerly course of the Nile was as long as that of the Proto-Congo, from the Congo-Zambesi divide to the Great Syrtis Gulf. Curiously enough, Livingstone, when exploring Lake Nyasa, was told by a native that Tanganyika was of the same shape as that of Lake Nyasa, but that the outlet was on the north of the lake, instead of, as in Lake Nyasa, on the south; as the native had not seen this himself, Livingstone dismisses the statement as a piece of Arab geography, but the fact

remains, that the M'fumbiro volcanoes, north of Lake Kivu, have only recently been thrown up; it may well be that the Arab slave-hunters, not long before Livingstone's time, did actually see Tanganyika discharging northwards, into the Nile.

The Nile, however, is by no means a simple river, and there is abundant evidence that important changes have taken place in fairly recent times. The most striking feature is the S-shaped bend in the Nubian region. Stretching across the southern bend, from some distance above Khartoum to Ambukol, where the river runs south-west, and then resumes its northerly course, there is a deep channel, the Wady Mokattem. It is now dry, but it once was the main stream of the Nile, making a straight course for the Blue Nile, from the Ethiopian uplands, in a north-westerly direction. There is no question here of head-stream erosion, or river capture, for the volcanoes in the Bayuda bend of the Nile, Magaga, Ghilif and Ghekdul, are the cause of the deflection, that is to say, the accumulations of lavas and ash piled up to such an extent that they turned aside the river. The Blue Nile, then, ran north-east, down the Wady Mokattem to Ambukol, thence along the bed of the Nile to Amara, and then out into the desert, past the oases of Charga, Dakhel and Farafra.

The Atbara, also, flows north-west from the same highlands as the Blue Nile; it joins the Nile above Berber, and flows in a straight course to Abu Hamed, and then turns south-west. Again, a deep wady continues the straight course of the original Atbara, cutting across the bend and joining the present Nile at Asaki, above Assuan; this is the Wady Galgabba, with its northern continuation, the Bahr-bila-ma, "the river without water" (not the river of the same name we mentioned in connection with the Siwa Oasis). The Nile, then, originally was two rivers running parallel. Owing to the failing of the Proto-Congo and the conversion of the open country into a desert, and consequent filling of the river-bed with sand, and also, probably, owing to the lowering of the bar of syenite at Assuan by the erosion of the river, giving the more easterly stream a more drawing power than its western neighbour, the former

worked back by a side-stream across the divide, and tapped the western stream. The lakes of Charga then dried up.

In Upper Egypt the Libyan Desert commences at the foot of the escarpment of Lower Eocene rocks, that form a plateau between it and the Nile. Underground water is plentiful, as the oases indicate, and underground water is everywhere associated with former streams above ground. We have reason, therefore, to continue the western Nile on the desert side of the escarpment, to Siwa, where there is the Temple of Jupiter Ammon. Here was once a populous Roman city, with every evidence of abounding fertility in the country around it. There is the other "river without water," the Bahr-bila-ma, here, which is connected with the present Nile through the Fayum. The Fayum is a depression into which a western branch of the Nile, the Bahr-el-Yussuf, discharges, and there is still a lake, the Birket-el-Qurun, in the depression, that serves as an illustration of what existed in most of the oases in bye-gone times.

The Bahr-el-Yussuf leaves the Nile a little below Assuan, and flows parallel to it for 120 miles; in the same way the original western Nile, leaving its present course at Amara, flowed on the western side of the Libyan Desert escarpment, and discharged into the Charga Oasis. There are two areas of lake-deposits here, with salt-pans, indicating the connection of the oasis with running water in former times. From Charga the escarpment runs westwards; following the foot of the hills, one comes to the Oasis of Dakhel (Dakla), which is of a similar nature. Thence the plateau trends north-west to Farafra. Siwa and Jarabub Oases lie at the foot of a table-land composed of sandy Mid-Tertiary deposits, that separates the Libyan Desert from the sea, and the escarpment runs, somewhat irregularly, east and west. These places were connected at one time with the present Nile by the Bahr-bila-ma, but if the western Nile did flow on the desert side of the plateau escarpment, as there is reason to believe it did, then, at an earlier stage it must have penetrated here also. There are a number of salt-marshes, or sebkhas, between Siwa and Jarabub, that are fed by underground water; they form a series of depressions connecting Jarabub with Augila. Rolfs conceived the project of trans-

forming this chain of oases into an inland gulf by admitting the Mediterranean waters through a cutting to the Wady Fareg or the Bir Rassam. A waterway, he thought, might thus be opened far into the arid Libyan Desert, the climate improved, and Cyrenaica converted into an island in the middle of the Mediterranean. Rolfs himself, however, gave up the idea after his expedition into the Libyan Desert, when it was found that Siwa alone, with its eastern extensions, fell below the level of the Mediterranean (Siwa -98, Sittra -80, and the Birket-el-Qurun -141 feet). Augila and Jalo were, on the contrary, found to stand 130 and 296 feet above sea-level, so that the marine inlet cannot have penetrated very far in recent geological times. Rudaire had a similar project in connection with the shotts of Algeria. Beyond these marginal floodings, no engineering feat can bring the Mediterranean into the Sahara, because it stands much above sea-level. In 1877 Donald Makenzie proposed a plan for opening Central Africa by flooding the Sahara; he published a book "The Flooding of the Sahara," which was widely read, and is the reason that the idea is so prevalent. There are no facts to support Makenzie.

As bearing on the question of the Proto-Congo, we find a very large western tributary of the Nile coming from the volcanic region of Darfur; this is the Wady Malik, that joins the Nile at Old Dongola. Now-a-days the Marra Hills have no moisture to spare for the plains, and the fact that a very large river once took its rise in these hills shows that the climatic conditions were very much more favourable at one time. According to our arguments, the Marra Hills lay in the bend of the Proto-Congo, and its once copious rainfall is readily explained by this fact.

In the Sudan the Nile has a swampy region, like Lake Chad, called the Bahr-el-Ghazal. There is a more or less well defined river-bed which bears this name, but it has practically no fall. On the east, the Sobat enters the Bahr-el-Ghazal on the same course, but flowing in the opposite direction, and if both rivers are in flood at the same time, there is a great congestion of water at the confluence. It is an axiom that when a river-system contains such a region of dead water, or when two rivers meet in such an unnatural

manner, that changes have taken place recently, and that the river has not yet adapted itself to the new conditions. Here, however, we come up against the Rift-system of East Africa, which is a region of block uplift, as well as of trough faults, and the whole original plan of the drainage is obscured. One is tempted to suggest that the original river-bed extended from the Marra Hills as the Bahr-el-Arab, then down the Bahr-el-Ghazal, down the Sobat, and out to sea by the Juba River; that the mountains of block uplift rose across this and turned the Sobat, from a south-easterly flowing river to a north-westerly one. Given sufficient time and no further shifting of the earth's crust, the Juba River will eat back through the highlands of Abyssinia, tap the Sobat, and actually cause such a river to come into existence.

At the time when such a condition of things obtained, the Rift Valleys of the Red Sea and Gulf of Aden had not yet been formed, and Arabia was joined on to the continent of Africa. Africa was then a symmetrical block, with a central extension north and south, together with a northern cross-piece, the West African shoulder being balanced by the Arabian shoulder on the east. The central portion was drained and fertilised by the Proto-Congo, flowing from the Congo-Zambesi divide to the Great Syrtis Gulf. On the west the Niger and the Igharghar drained the country from south to north, and on the east the Arabian shoulder was drained by the twin Niles. The whole of the continent was then as well watered as the North American continent. With the Rift system we cannot deal here, but for the rest, the drying up of North Africa is due to the capture and diversion of its natural river system, whereby the waters which once traversed the continent are now hurried in short, precipitous courses to the sea.

SOUTH AFRICA.

In South Africa we have the central depression of the Kalahari, surrounded on all sides by high ground. In the centre lies Lake Ngami, corresponding, in many respects, with Lake Chad. East of Lake Ngami, there is another great depression, occupied by the Soa Salt Pan and the

Photo. by] **PLATE V. The Cunene River Cataracts.** [R. Schlange Tsumeb.

Photo. by] PLATE VI. Kuring Kuru, on the Okavango River. [R. Schlange, Tsumeb.

Ntwetwe Pan, which are the level bottoms of the Makarikari depression. The Soa Pan covers an area of about 2,000 square miles, and is 56 miles from north to south; the Ntwetwe Pan is 86 miles long, by 5 to 8 miles broad. If the whole of the Makarikari depression, which lies some 150 feet below the level of Lake Ngami, were to be filled by the overflow from that lake, through the Botletle River, a lake of 15,000 square miles in area would be created, a sheet of water larger than Tanganyika, 12,700 square miles, and more than half the size of Victoria Nyanza, 26,828 square miles.

The Soa and the Ngami Lake are connected by the Botletle River, and the relationship between the two is the same as that between the Bodelé and Lake Chad, the Botletle River representing the Bahr-el-Ghazal. To the south-west of the Soa Pan, there is another pan, Andersson's Vley, connected by a dry river-bed with the Soa system, and from here to the Molopo River there are the sand-hills of the Kalahari; these are what the French call "Ergs morts," that is, dunes that have been anchored by vegetation. There are, however, a succession of vleys which are most probably portions of the river that have been sanded up, and certainly the great floods of the Zambesi in 1917 seem to have reached the Molopo and caused it to run in flood nearly to the Orange River. The sand belt occupies the centre of the course of the original great river of South Africa, which I am going to call the Proto-Orange, in accordance with the nomenclature adopted in the case of the North African rivers. This river failed owing to the capture of its head waters.

The original Central South African river, this Proto-Orange, rose in the highlands about Tanganyika, and is now called the Loangwe River. This flows south-west and joins the Zambesi near Zumbo; thence it originally flowed up the channel of the Zambesi to Wankie, where it met the Batoka basalts, and then followed a course parallel to the Deka fault, in a valley, the Gwai Poort, still open to it, to the Soa Pan. From the Soa Pan it flowed to Andersson's Vley and the Molopo River, at Mokopon, and so out to sea by the lower Molopo and the Orange River. Livingstone, in his

"Missionary Travels, 1857," page 477, alludes to the ancient river which once flowed from the Linyanti (Chobe) basin to the Orange River, so I am stating no new idea of my own, but rather developing the facts recognised by actual travellers.

The original coastal rampart, on the east, was the Kirk Range, that skirts the western shore of Lake Nyasa, and is continued on the south as the Melsetter Range; this latter forms the boundary between Southern Rhodesia and Mozambique. The original Zambesi rose in these hills and flowed south-east to the sea. On the inland side, the river ran in its present channel, but north-westwards, and then westwards, to join the Loangwe River. The original rampart is now much degraded by weathering and erosion, where the Zambesi traverses it; at one time it was, judging from some of the peaks left standing, like Mt. Dombo, 6,240 feet, at a general average height of 6,000 feet, which is a constant level for all the coastal ranges of South Africa. From this range the Zambesi had a run of 350 miles to the sea, or a fall of 17 feet to the mile. On the inland side, the river had a course of between 2,500 and 3,000 miles, or about two feet to the mile; in other words, the erosive power of the coast stream was 8½ times greater than that of the inland one.

The place where the Zambesi originally rose is now occupied by the Kebrabasa Cateracts, which have a fall of 160 feet. On the right bank stands the mountain Zakavuma, and on the left Morumba, some 3,000 feet high. The river is jammed between these two mountains in a channel with perpendicular sides, and less than fifty yards wide; the rocks are water-worn and smooth, with huge pot-holes, even 100 feet above low-water. We can at once recognise the relationship of this gorge to that below Stanley Pool on the Congo and the Falls of Bussa on the Niger. The swell of the land in which the Victoria Falls are situated, runs in a north-north-westerly direction, and is a secondary water-parting; at one time the Zambesi cut back to as far as the Batoka Gorge, and all the water above the Falls was restrained within the Ngami depression, with an outlet to the Makarikari, and so through the Kalahari to the Orange

River. This was actually the arrangement of the water system that the Portuguese imagined to exist, before Livingstone ascended the Zambesi from the mouth to the Falls in 1860; it may be only a coincidence, based on faulty information, since even the early missionaries at Zumbo could scarcely have been there before the Zambesi breached the rampart of the Batoka basalts, but there is the similar evidence from Arab sources about the Lukuga outlet of Tanganyika.

The Makarikari depression to the east of Lake Ngami is a vast plain, with the sides rising gradually or in terraces, like in the old lake Bonneville in Utah. In this plain the salt pans lie sunk a few feet beneath the general surface, and are occasionally filled with water. Formerly there was a lake, Kumado, in the southern corner, corresponding to the present Ngami in the bed of its former extension; in Chapman's time (1852) it was still a marsh, in the centre of which the Chief Chapo had his town. The fact that in both depressions the water accumulated in the southern ends leads one to think that the natural outlet was formerly here, and not to the north or east. The Gwai Poort, "the land of a thousand vleys," forms a long bay in the high walls that separate the depression from the Zambesi valley, but it is now partially choked up with sand. On the south-west, the valley of the Gwai Poort is continued by the Epukiro River. The rivers here are shallow, grass-covered valleys practically without gradient; they were once true river-beds, but they have become choked by silting or the accumulation of wind-borne sand, and after rain, instead of being filled with running water, they become a series of vleys. A still further desiccation and all connection with a river-system became lost, and the depressions became isolated pans. The physiographical features of this part of the country render it probable that the Gwai Poort was the continuation of the Loangwe River, before the Zambesi cut across it. The great cleft of the Loangwe may have been helped by earthquakes that fissured the land; certainly the valley is one of great seismic activity, and recently the town of New Langenberg, at the head of the river, was totally destroyed by earthquake shocks, and the rift of the Victoria Falls may be due to the same cause.

My interpretation of the Loangwe River has been disputed, but a glance at the map will show any unbiassed person the reasonableness of my contention. In a normal river the plain is inclined sea-wards, and the river flows through the centre of the valley, with the tributaries flowing in the same direction. Both the Kafue and the Loangwe, however, flow, not down the river-plain to join the main stream, but apparently up-stream. The course of the Zambesi is roughly, from west to east, but the Loangwe and the Kafue flow from north-east to south-west, so that, unless we adopt my explanation, we should have to suppose that originally these tributaries flowed up-hill.

For the Kalahari side we have very full descriptions of the country by a number of travellers, whose books make some of the most romantic reading in the history of Africa. The following is a short list of the more important works that I have before me:—

F. Galton—"Travels in South Africa," 1853.

C. J. Andersson—"Lake Ngami," 1856.
"The Okavango River," 1861.
"Notes of Travel," 1875.
"The Lion and the Elephant," 1875.

William Cotton Oswell—"Life of," 1900.

D. Livingstone—"Missionary Travels," 1857.
"Expedition to the Zambesi," 1865.

T. Baines—"Explorations in South-West Africa," 1864.

J. Chapman—"Travels in the Interior of South Africa," 1868.

F. Selous—"A Hunter's Wanderings in Africa," 1881.

G. A. Farini—"Through the Kalahari Desert," 1886.

A. Schultz and A. Hammar—"The New Africa," 1897.

W. C. Baldwin—"African Hunting and Adventure," 1894.

A. St. Hill Gibbons—"Explorations in Marotseland" (Geographical Journal), 1901.
"Explorations in Central Africa," 1898.

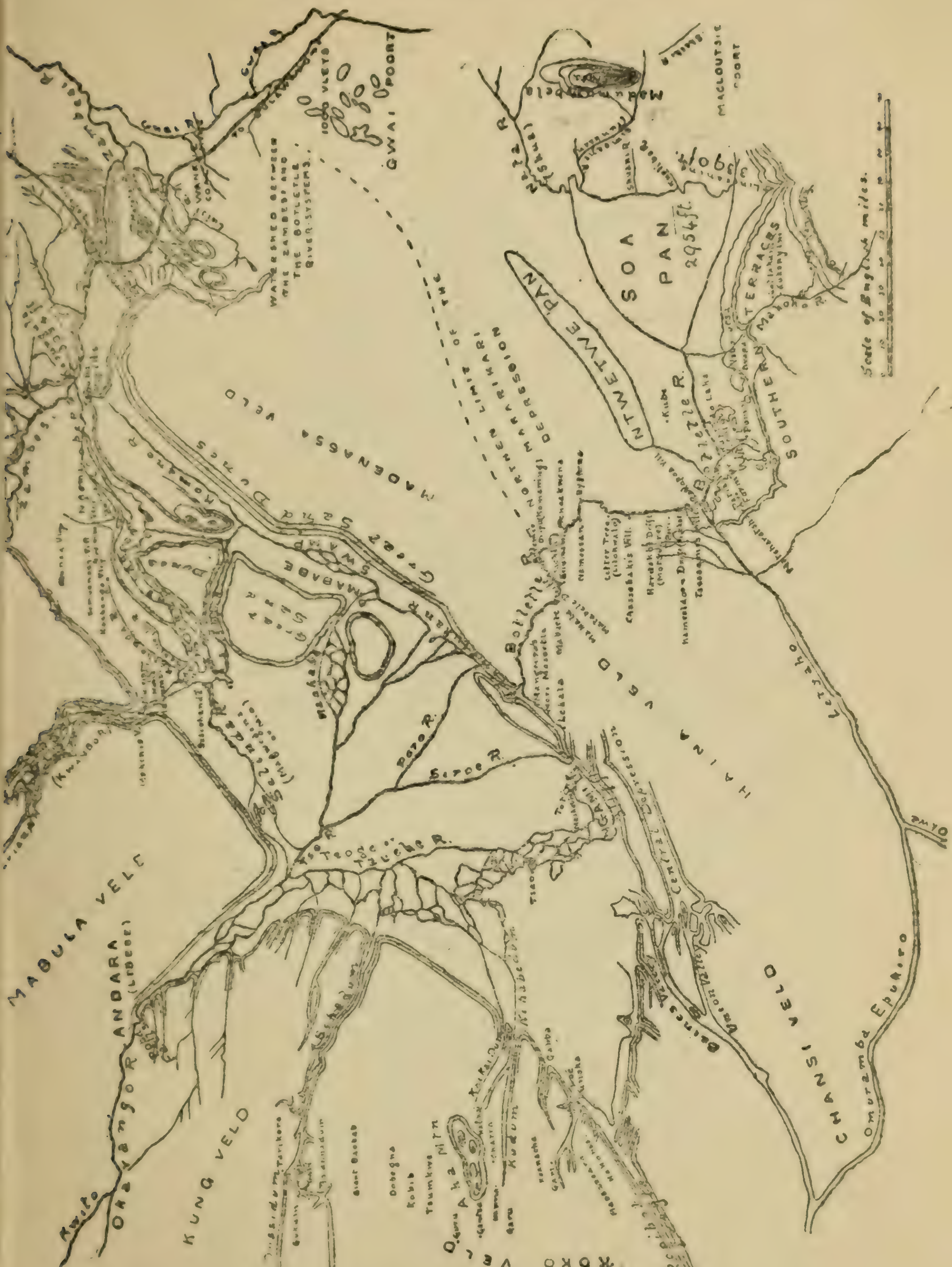

Fig. 7. Map of the Ngami Region, after Passage, Percy Reid and St. Hill Gibbons.

S. Passarge—"Die Kalahari," 1904.

A. W. Hodson—"Trekking the Great Thirst," 1912.

It will be noticed that I have put Oswell before Livingstone. The truth of the business is that Oswell, an Indian Civil Servant on leave in South Africa, started to trek to Ngami, and on his way he met Livingstone at Kuruman. Oswell asked Livingstone to come with him as his guest, providing him with a waggon and gear. When the importance of Oswell's discoveries became known, the Royal Geographical Society wished to present him with its Gold Medal, but Oswell asked them to give it to Livingstone instead. Later, when pressed to write an account of the journey, Oswell burnt his notes, to prevent anyone taking "the wind out of Livingstone's sails." Oswell's son, in writing the life of his father, came across a map of the Ngami region, drawn by Oswell in 1852, in which are marked the Okavango, Chobe, and Zambesi Rivers, and, of course, Ngami. The Victoria Falls, which the natives call Mosioatunya, is also marked, but Oswell never saw the Falls. There is no object now in withholding the credit of the discovery of Lake Ngami from Oswell; nothing can detract from the fame of Livingstone, and Oswell's well-meant generosity should not stand in the way of his recognition.

With this survey of the river-systems of Africa as a whole, we are in a position now to discuss the South African rivers in detail. Partly with the aid of the literature just mentioned, and partly from my own observations, I have been able to put forward a plan for conserving the waters of the Cunene, Okavango and Chobe Rivers, and impounding them in a great natural reservoir, the Makarikari. The Makarikari has been dry now for over 100 years, and it may take years before we can fill it up to its former level; meanwhile, we can short-circuit the water past the depression, and lead it on to land in the Kalahari, turning that wilderness into the most fertile region in the world, and suited to white settlement. The surplus flood waters would run into the Makarikari, and when the seepage had been made good, a vast lake would exist to supply South Africa with moisture, and stop the desiccation that is ruining the land.

PART III.

THE REMEDY FOR THE DROUGHTS IN SOUTH AFRICA.

The area in which the diversion of the rivers is proposed, lies between the Victoria Falls and the Great Falls on the Cunene. I should have liked to include the Zambesi River with the others, but I have been advised that no meddling with Victoria Falls would be allowed; in the first place, it is one of the wonders of the world, and in its sublimity has captured the imagination of countless thousands of people who would raise an outcry if the waters were turned into their old channels, southwards, and the Batoka Gorge were to become a dry canyon like the Magwa Cleft in Pondoland. In the second place, the Victoria Falls Power Company has acquired rights over the water, and there would be trouble in acquiring them back for the good of the Nation. I have therefore worked out my scheme without touching the Zambesi. I believe that I can obtain sufficient water from the Chobe and Okavango Rivers to fill the Makarikari. This water, saved from the sea, will be evaporated, and will fall as rain during the next year. Meanwhile another rainy season will fill up the Makarikari. The rains from the previous filling will cause the smaller rivers to flow, so that more water will be available the second year for the reservoir. In time, all the Kalahari rivers will start running; each year's flood, bringing water from outside, will reinforce the previous stock till the Kalahari is entirely regenerated. In addition, I propose to restore Ovamboland to its former swampy condition, in which it played a notable part in the supply of moisture to the Angola Highlands. These hills are the source from which rise the Chobe, Okavango and Zambesi Rivers, as well as the Congo on the north and the Cunene on the east. All these rivers are failing. With the Ovamboland swamps in their old condition, the rains on

the Angola Highlands will be increased, and consequently the rivers that rise in them will flow with greater volumes. So, from both sides, I look to obtain larger supplies of water than are carried at present by the rivers. When I was in Ovamboland I asked whether the natives would object to having their country turned once more into a swamp. The answer was most emphatic, from king to the poorest subject. The Ovambos are accustomed to live in swampy ground, and their staple food, mahonga, grows best in such ground. Anything is better than present conditions, and they pointed to the road from Ondongua to Tsumeb, 200 miles, strewn with the sksletons of Ovambos who had perished in the famine of 1915; with the swamps they may suffer a little from malaria, but this is better than perishing from hunger.

The Ovamboland Plain.

The western half of the project for filling up the Kalahari lakes falls generally into the vast river plain of Ovamboland. This part is important for several reasons. In the first place, when the scheme is in working order and the water of the Cunene River, after traversing Ovamboland and restoring it to the condition of 1860, when Andersson described it as "glorious," runs into the Okavango River, it will reinforce this river so much that it will be able to clear its channels of the ever-encroaching sands of the Kalahari. But far and away more important than this will be its effect on the rainfall of the Angola Highlands. These highlands are the source of the Cunene, the Okavango, the Zambesi, and several of the head-streams of the Congo. The Ovamboland plain which lies to the south extends over an area of something like 70,000 square miles. In former times the whole of this plain used to be flooded annually from the Cunene and Okavango Rivers, and the enormous evaporation from this formed a very important factor in the rainfall of the Angola Highlands. Nowadays, not half of this plain is flooded, and the portion receiving the flood-waters is becoming smaller every year. It is clear that if this Ovamboland plain becomes as waterless as the adjoining Kalahari the effect on the Angola Highlands and the great rivers that rise in them will be disastrous.

It will be seen in the sketch map that there are several spillways that lead out of the Cunene and Okavango Rivers; from the former there are the Ovale, the Kwamatua, and the Itaka. These spillways are shallow river-beds opening on to the main rivers at a few feet above the level of the normal flow; when the rivers are in flood, the water banks up at the cataracts and a certain amount flows out along these spillways. The Ovambos distinguish these shallow channels from the deeper river-beds, calling the former "Oshanas" and the latter "Omlongas." The word "Omaramba," which appears in most maps of this and the Kalahari country, simply means "river-bed," and is applied equally to the smallest oshana and the biggest river, such as the Okavango and the Zambesi. On the Cunene side there are several oshanas that lead out on the east side; the river is banked up above the level of its flood-plain, and consequently a certain amount of water spills over on the west bank, but as there is high ground here, the water collects in a number of vleys lying parallel to the river. In flood-time the east side of the river is practically a labyrinth of oshanas, but there are three principal ones, the Ovale, the Kwamatua and the Itaka. The last is not marked on the German or Portuguese maps, but it is quite unmistakable and, indeed, in the dry season it is the main roadway to Erickson's Drift; it then has a hard clay floor, on which a motor-car could travel at 40 miles an hour. On the Okavango side, the first spill-way is the Otjimpolo River, which I have traced right down to the Etosha Pan; the Tandawe joins the Otjimpolo River from the Okavango above the Portuguese border. The Hyaena and Lion Rivers probably do the same, but the bush was so thick at Kambonde's Vley that I was unable in the limited time at my disposal to investigate this point; native evidence was against any connection, in fact, several native hunters who knew the country intimately, stated definitely that there was no sign of a river-bed within three days' journey to the east. I am certain, however, that the connection used to exist, but has become sanded up; in the same way Mr. Breijer's sketch map shows a former connection of the Lion River with the Etosha Pan. Further down the river the Fontein River leads out of the Okavango,

and could be used to irrigate a considerable distance up the Omatako; the water takes a side channel to Gasamas, and then passes by a long string of vleys into the Ovambo River, and so into the Etosha Pan. I was very careful to verify this, and obtained definite Bushman evidence that it was so. In 1917 the flood came over and filled the Ovambo River to the tops of the banks, and I have photographs of it in this condition. I followed the river up from Tsintsabis and saw the flood effects, and some six miles from Tsintsabis there is a wide oshana leading into the main river, some four feet about the latter, which showed every evidence of having led water into the Ovambo River. When the flood subsided it left pools in the river, and barbel as big as a man's thigh were caught at Tsintsabis, this is on the evidence of the Military Police stationed there, and these barbel are typical Okavango fish.

C. J. Andersson, who was on the Ovambo River in 1857, was intensely puzzled by the flow of the stream. He described it as "having been noted by previous explorers as a current of some pretensions; broad, deep, and running between regular, well-defined banks. Just a year before, Messrs. Green and Hahn had found it an almost continuous stream, abounding in water, flowing westwards, and finally forming the lake Ondowa." It was, when Andersson saw it, quite dry, or at most, capable only of occasionally filling pits and wells. How then, he asks, or whence does it receive its temporary flood? "It appears utterly impossible that such a stream should take its rise in the sandy districts stretching far and wide to the eastward. Nor is it likely that it is fed by the great permanent river, the Okavango (though this supposition seems at first sight apt to solve the mystery); for at this point the Ovambo River (according to boiling water observations) is several hundred feet higher than any of these parts of the Okavango visited by me; whilst the travellers I have just named could not possibly have been deceived as to the direction of the flow of water."

I have studied the whole question very carefully, and believe that Andersson's surmise, which he dismissed, is the correct solution of the riddle. I also took barometer

readings which I know were misleading. Mr. A. Karlson at Tsintsabis obtained a reading of 350 feet above Namutoni; this would, in a distance of 70 miles, give a fall of 5 feet to the mile. The Okavango, with a fall of one foot to the mile, has a flow of five miles on hour, and this is the most steeply graded river in Ovamboland. If the Ovambo River had a fall of 5 feet to the mile, it should be a stream with a very rapid current, whereas as the accompanying photograph shows, there is hardly any current at all. The flood rises slowly without rain in the neighbourhood, fills the river bank full, and slowly subsides, the waters flowing into the Ondowa Pan, and then into the Etosha. There can be no doubt that the Ovambo receives its water from the Okavango in the same way as the Tandawe, Ombungu and Gamka Rivers do.

The following two views on the question are interesting as affording a possible alternative solution. The first is from Mr. Jack C. Kruger, of Guchab, South-West Africa, who has been exploring the northern part of South-West Africa and Angola for the last seven years, and the second is from my very good friend and host at Namutoni, the late Mr. J. W. F. Breijer. Mr. Breijer, shortly after the patrol of which he speaks, left for Pretoria, where he contracted pneumonia and died; he was Game Ranger at Namutoni, and through his activity in suppressing poaching the thousands of game, zebras, wildebeeste, gemsbok, giraffes, koodoos, etc., had returned to their old drinking-place. It was a post of considerable danger, for the Heikum Bushmen around were quite wild. As an instance, I may quote one expedition we made together. We had gone to an old shooting-place that used to be occupied by Erickson, "Karawapa," as he was called in the district, Andersson's assistant; there is a spring here called Hoas, and the game that are to shy to come and drink at Namutoni satisfy their thirst here, and then scamper into the Etosha Pan and rest there for some time. Mr. Breijer had gone off to try and obtain a springbok for dinner, while I was too tired from my camel ride to assist him, and lay down under the shade of the crumbling walls of Erickson's house. After a couple of hours a Bushman suddenly appeared from nowhere. I gave

him some tobacco, and then we sat looking at each other till the hunters returned. One of Breijer's men interpreted, and we learnt that this Bushman had done a year in jail for shooting a gemsbok. The whole party of us might easily have been shot in revenge, and the lions would have removed all traces the same evening. I take this opportunity of placing on record the services of one of those pioneers whose lot is cast in the waste places of the earth, and who did an immense amount of good in his short life.

Mr. Kruger states that there can be no doubt that the Cunene River once flowed into the Etosha Pan before the outlet through the great rapids near Naulila (Hinga) had been eroded. The only possible outlet from the pan is to the east along the Ovambo River. Taking into consideration the limit of exactness of aneroid readings, no difference in altitude can be recorded for a considerable distance, but at Tsintsabis, about 60 miles east of Namutoni, the altitude has risen 300 feet. This would mean that the drainage of the pan must join the Lion River. The only aneroid reading there is on record of this almost unexplored region was taken by Seiner, who gives Tchitchib at 3,230 feet. This observation would denote the Cunene River as an old tributary of the Okavango, and this fact would join in with the general orographical aspect of all the rivers that come down from the watershed near the Lobito railway. All of the rivers run in a southerly direction, and turn east in the southern part of Angola.

Mr. Breijer wrote from Namutoni, dated 12th April, 1919: "My last patrols have taken me in a good way into the Sandveld (Omaheke); there I have seen various different omarambas in which you may be interested. The main one is that which I followed from Small Bezib to Osohama. This is undoubtedly a very large one, quite as large as the Mlongo Inene * (Ojimpolo River, which we had crossed together a short while previously). The banks are very well defined, having a depth of at least 30 to 40 feet before flowing into the Andoni Flats. It is not too wide there, I should say

* All big rivers are called Mlongo Ineni; the Portuguese have turned the "ineni" into Cunene, and the "mlongo" into Congo.

80 yards, more or less; further up it reaches a breadth of from two to three hundred yards, with a depth varying from five to ten feet. Unfortunately I could not follow it the other way, but at Xoabab, I also found a well-defined river-bed, and I would not be at all surprised if that was the same river. I think it is fed by the floods from the Okavango River. These omarambas all seem to run parallel to the Ovambo River; the small omaramba at Ekakab runs into the Ovambo. At Xaichaus, between Large Bezib and Ekakab, there is also a water-course, and I think that that is the same one that I saw at Ekakab, but I am sure that the Small Bezib-Xoabab River and the Xaichaus-Ekakab River are quite distinct. Further, you may be interested to know what water there was in the Etosha Pan (after the rainy season). The rainfall here was only nine inches this year. The sides of the pan are now dry as far as the eye can see. The depth of the water in the pan in the middle of March did not exceed one foot. I walked from Hoas to Uitsab; the water at its deepest was just under the knee, and for the greater part of the way did not reach above the ankle. The maximum depth was just over three feet." In regard to the last remark, it must be remembered that in these shallow pans the wind drives the water before it, so that the water may be quite deep on one side, and the pan may be quite dry on the other. It often happens in the smaller pans in the north-west of the Cape, that one may be trekking along in a waggon over the dry surface of the pan, and then, when the wind drops, the water returns and makes things very unpleasant.

The question whether the Ovambo will flow eastwards when the level of the Etosha Pan is raised 60 feet is really of no consequence to the main object of the scheme. I still believe, from what observations I was able to make on the spot, that it will. The matter will have to be settled by direct levelling. As long as the Ovamboland swamps are restored and the Etosha filled, then the evaporation will reinforce the head-streams of the Okavango and Chobe, besides relieving to a most notable extent the aridity of the South-West Province. I must explain that the country is so flat that these oshanas and omlongas of the Ovamboland plain

do not flow like an ordinary river; for one thing, their beds are full of sand. When the Cunene or the Okavango rise above a certain height the water pours into the spill-ways and flows quite strongly for a short distance; then the water encounters a dam of sand and comes to a standstill until it either washes it away or filters through it to the next open portion of the channel. In that way the current is so slow that the Ovambo in full flood appeared to have no current at all, and a stick thrown on the water would remain stationary for a considerable time before it eventually floated down-stream. This sluggishness also applies to the Cunene, which was measured by the same stick method; a stick took half an hour to float a hundred yards, that is, when the river was in normal, not in a swollen, flood. Such evidence makes me believe that the Portuguese estimate of the fall of the Ovamboland plain inAngola as one foot in the mile is excessive; I obtained the same between Namutoni and Ondongua by barometer readings, but on my return later in the season I found no difference in level whatever. The stick method applied to the Okavango gave a flow of five miles an hour, and here the gradient is reckoned at one foot to the mile.

The river system of the Ovamboland plain is so extraordinary that I believe it cannot have a parallel anywhere; these looping spill-ways uniting in the Etosha Pan must have some reason for their existence. The explanation seems to me to be as follows: The cataracts of the Cunene are of comparatively recent date; formerly the Cunene flowed directly into the Okavango. The latter river is encumbered with cataracts, which impeded its flow, consequently the Cunene having only a very feeble fall, had to find some outlet for its energy and cut sideways, and naturally on the side away from the mountains. In this way the river formed ever wider loops to the south until it came up against the hedge of hills which borders the plain on the south, cutting as it did so the vast peneplain, as the Americans call it. This is the Ovamboland plain, covered with white river sand; no stone is to be found north of the Etosha Pan. It is covered with bush and forest, thorn, mopani and, along the Otjimpolo River, teak. In this bush there are vast natural clearings, some 40

feet lower than the general level of the bush country round them; these clearings are each occupied by different tribes of the Ovambo, Ondonga, Ombarantu, Onganjera, Ovakulukathi, Ovakualuthi, Ondombothora, Ovaquambi, Ovagunyama, and so forth, tribes, which supply the labour for the mines and railways of the South-West Protectorate. These clearings are covered with hyphaena palms and magnificent morula and fig trees, in between which the natives plant their mahonga, a sort of kaffir corn. The Kalahari, which borders the Ovamboland plain on the south-east, is a similar sand country covered with red, that is, blown sand. In the dry season the clearings are wastes of dazzling white sand, but in the rainy season, since the country is flat and there are no rivers with sufficient fall to take the water away, about half the country is under water, and the natives gather water-lily roots in what was a few weeks previously a desert. In addition, formerly the country received flood waters from the Cunene and the Okavango Rivers. The country requires this annual flood, the Efunja, because the rainfall is totally insufficient to support the tropical vegetation. The following is the rainfall at Ondongua for the last 12 years:—1906-07, 17.5 inches; 1907-08, 11 inches; 1908-09, 37 inches; 1909-10, 20 inches; 1910-11, 9 inches; 1911-12, 25 inches; 1912-13, 12 inches; 1913-14, 15 inches; 1914-15, 12 inches; 1915-16, 11 inches; 1916-17, 29.2 inches; 1917-18, 19.6 inches; an average of 18 inches, with a minimum of 9 inches.

When the rock-barrier on the west was breached at the Rua Cana Cataract, the Cunene poured over the falls and was hurried away to the sea. Since then no floods have been sufficient to carry water from the Cunene to the Etosha Pan. Every year the river is sawing down the rocks of the cataracts, and it is becoming more and more difficult for it to spill over into the oshanas. In Nangora's time, that is, when Andersson was in Ondonga,* about 1850, the oshanas used to flow past the chief's kraal, and the people used to catch the river fish in basket traps, and in fact used to live

* Ondonga is the name of the district and tribe inhabiting that district; Ondongua is the administrative centre and residence of the Commissioner.

on the fish for a considerable portion of the year; nowadays the floods do not come near the place, and Chief Martin, Nangora's successor, keeps some of the fish in a water-hole as royal fish, and as relics of the past. The time is not far distant when the Cunene will have cut down so low that no water will spill over into the Ovamboland plain; the oshanas, then, instead of being the channels by which the country is supplied with water, will become drains by which the water is drawn away from it. Ovamboland will become a waterless tract like the Kalahari; the natives will have to be accommodated with other territory, and the arid conditions of South Africa will be accentuated. To put it in another way, we have in Ovamboland a clear case of a fertile district being converted into a desert, and if one requires to be told what the effect of a desert is on the adjoining country, I can refer him to descriptions of Egypt.

On the Okavango side, the Caundu River comes out of the main stream far up near the head waters, traverses the maze of oshanas in the Cafima district, and the river-bed passes about twelve miles east of Ondongua as a well-defined course. It is quite dry now, and only fills from the sides when it rains, but the people tell of the time when they used to make sacrifices to propitiate the crocodiles in this river. At one time it formed a barrier which separated the two halves of the Ondongo nation; on the west was Kambonde's country, the Umkunda, or district of the Morulas, Onamahongo, and on the east was Nechale's country, the Oshitombe Umkunda . Nowadays this formidable barrier is only a sandy depression, and the Ondonga nation is no longer divided.

The next spill-way is the Otjimpolo River, which is first turned out of the main stream by the Maculungungo Cataract, but the Balacuco and Tandawe Rivers join it lower down. At Otjimpolo Fontein the river has built for itself a dam of sand and debris, which effectually cuts off the lower portion of the river. I struck the Otjimpolo River in the heart of the Omaheke, on my way to Kambonde's Vley, and I questioned some old native hunters who were with us as to when the river had last run; they said no one living

Photo. Ly] **PLATE VII. Bushman Werf near Ondera.** [R. Schlange, Tsumeb.

PLATE VIII. Bushmen at Tsintsabis.

The Ovambo River at Tsintsabis a year after the flood.

remembered the river to have flowed, but they said it did so in Nangora's time, say, sixty years ago. Besides the dam below Otjimpolo Fontein, the wearing down of the cataract has naturally tended to lessen the flow, and I doubt whether it will ever be practical politics to revive this river. That it was once a very big river was evident from the wide flood-plain on the east bank. There are a number of vleys on this plain, lying parallel with the river, of which Kambonde's Vley is the best known; it is marked on the maps of the country, but is placed some 25 miles to the east of its actual position.

Kambonde's Vley is really a collection of four vleys, joined by an oshana, and lying at right angles to the river, which is five miles distant; the first three lie in a semi-circle, and the fourth, Kambonde Ineni, lies east of them. The country round here is forest, the big trees being mostly Karmeel Doorn and Teak, but there is a dense undergrowth of smaller thorn-trees and Mopani. The direction of these vleys suggested that they formed part of an oshana which once connected with the Okavango by the Hyaena River, but if that had been the case formerly, all traces of the connection has disappeared. There is another vley between Kambonde's and the river; it is called Nanguti, and is merely one of the numerous vleys that we encountered travelling down the east bank. Some ten miles from Kambonde's Vley, to the south-west, there is a deep water-hole dug in the bed of the river, called Igola, but it was dry when we arrived there. The teak trees here were very fine, and were seemingly in a flourishing condition; away from the river, however, a large proportion of them are dead. The river-bed here lies some 20 feet below the flood-plain, and is 30 to 40 yards across; it could easily accommodate the Cunene River. The Otjimpolo River traverses thick bush country to Ombuga (Yangwari's Kraal), and thence goes south to enter the Etosha Pan in the centre of the northern side. Towards the Pan the river valley becomes wider and deeper, and forms a very noticeable depression in this flat country; the clay bottom forms a good motor road from the pan to the main road past Nomteli. The whole of the bush country is full of small vleys, called "Etheas"; they are elongated in a

north-easterly direction, and are parts of oshanas that once communicated with one or other of the omlongas, or better defined rivers. The bank of sand by which they were originally stopped is in most cases well shown even now. In fact, there is no spot in the whole of the Ovamboland plain which has not at one time been part of a river bed; this fact comes out very clearly in the rainy season, when the country is a succession of islands with water everywhere around.

The Etosha Pan.

The Etosha Pan is a vast level floor of slaty green clay; when the surface becomes wet the colour changes to a yellowish green. The colour is due to a vegetable growth. I have kept this blue-green slime in water, and have found that it rapidly increases in bulk, but the only organism that I have found was an extremely small spherical bacterium. There forms on the surface flat lumps of white flint, similar to the white flint that forms in the vleys of the Cape Province, from diatomaceous deposits. When the wind blows over the dry surface, it raises a cloud-like steam. On one occasion I was enveloped in the cloud, which was thick enough to blot out the landscape; there was no grit in the cloud-dust, nor was there any saltiness in it; I believe this dust to be nothing but minute spores. The edge of the pan is white chalky clay, which material underlies the whole pan. From the pan one climbs out on to banks about 4 feet high, and these banks are the edge of the great bare grass-covered flats that surround the pan on the north. Nothing can be done with these flats, as they are so nearly at pan-level and the roots of plants would, when the soil was moist, find stagnant water at a very slight depth. The flats stretch from Andoni to Namutenja, 10 miles south of Nomteli, and then westwards to the river-beds that come down from Ondongua. Between Andoni water-hole and Nomteli water-hole, a distance of 55 miles, there is no water, and this stretch is an extremely trying one for the slow ox- or donkey-wagons; as a matter of fact, the wagon I was in, which had a team of 20 oxen, what from the heat on the open flats and the want of water, barely got through. On the north of the flats is the bush

country that I have already described, forming an encircling wall, some 40 feet high.

At the north-west corner of the pan, the rivers that come from Ondonga enter it by fairly deep, donga-like channels. All of these come either from the Cunene or the Okavango, except the Cariango or Cuvelai, which has a separate source in the Angola Highlands. There is an island here made of Kalahari limestome, which, with an outcrop on the same parallel on the east bank of the Otjimpolo River, is the last appearance of anything in the nature of a stone to be found till the hills of Angola are reached. The west bank of the pan is similar grass flats, raised 4 feet above the pan-floor, but here the flats merge into open grass country 40 or 50 feet above the pan. The southern border of the pan is made of Kalahari limestone, which may approach the pan as a wall 40 feet high, or the limestone may be concealed by sand covered by bush. The border is serrated, and long tongues of grass flats penetrate from the pan into the higher ground. It is on these flats that the countless thousands of zebra and wildebeeste graze, for whose protection the pan has been proclaimed a Game Reserve. According to one of my informants, these tongues penetrate so far as to pierce the edge of hills separating the Etosha basin from the drainage area of the Ugab River; in fact, the Germans had a project to fill up the Etosha Pan and to irrigate from it along the Ugab. According to the maps, however, the level of the Ugab at Outjo, 80 miles south of the pan, is considerably above the level of the pan, and the matter must be left till a survey is made to settle it.

The Kalahari limestone, of which the country south of the Etosha Pan is made, and which extends eastwards beyond Tsintsabis on the same parallel, forms an inclined plain bordering the Otavi limestone hills. It has every appearance of having been formed under a covering of sand, composed largely of grains of limestone. Over large areas, now, the sand has disappeared, and the surface is a most heartbreaking jumble of limestone blocks, weathered into all sorts of jagged shapes. It is covered with thick bush that in the dry season appears to be dead, but when the rains come the

sap rises, and although it may not reach the ends of the branches, it is sufficient to make the trees look green. There are a few wells dug in the limestone, which give a meagre supply of water. At the edge of the Etosha Pan there are several springs, of which Okaukweyo, Hoas and Namutoni are the principal.

Namutoni is one of the three great forts that the Germans built to protect them from the Ovambos; the other two are Zessfontein and Okaukweyo; Tsintsabis is smaller. It stands on a lake terrace 25 feet above the pan; behind is another terrace 40 feet above the pan. The edge of the terrace is very well shown towards the Ondowa Pan, a small pan 10 miles across, which is connected with the big Etosha (Etosha means pan) by the Onsila channel. This edge is an abrupt bank leading down to a lower terrace, 10 feet above the pan, and this, with an equally abrupt descent, leads on to the grass-covered surface of the Ondowa Pan. This last is surrounded by similar terraces covered with thick bush; on the east the bare pan-surface appears, and through the middle of the pan the Ovambo River meanders. In the limestone of the 25 feet terrace there is a mud-hole, about 30 yards across, filled with a luxuriant growth of reeds, and from opposite sides of this a furrow leads out a magnificent stream of water. Unfortunately, nothing will grow under irrigation here, so the water is allowed to run to waste down to the Ondowa Pan, but in doing so it forms a wide strip of vley ground at which thousands of big game drink, and in which large numbers of water fowl settle. About three miles to the south, there is Klein Namutoni, a similar mud-hole, but from which no water issues. The Hoas springs form at the base of the limestone terrace, and are not very strong, but are permanent. The main interest of Namutoni lies in the terraces, which show that the pan was once filled up with water to the 25 feet level. From what I could see, if the Etosha Pan were to be filled up to 20 feet, the water would flow far up the Ovambo River; the water, if kept at a steady level, would percolate through the sandy country between the Ovambo River and the Okavango, and would eventually reopen the channel connecting the two rivers. In

this connection it must be remembered that the Okavango is lower now, owing to the erosion of its bed, than it was when the two rivers originally communicated with one another, so that it should be easier on that account to reverse the flow; the matter must, however, be settled by actual levelling. At 20 feet the whole of the grass flats bordering the Etosha Pan would be covered, and the area shown on the map would be about doubled; these flats are the most useless, miserable country imaginable. The Bushmen burn the grass, and after rain the grass grows, and the game feeds on it for a short while, but the grass soon withers, and for the rest of the year the flats are a howling, empty waste, uninhabited and uninhabitable. If the water-level were to be raised 40 feet, the area of the inundation would be very slightly increased, but I doubt very much whether so much water could be collected from the Cunene alone, seeing what a quantity will be required to supply the tropical vegetation of Ovamboland, and if it were impounded in the Etosha, whether it would stay there, seeing that the Ovambo River, and probably the river-bed north of it, opening out on to the pan at Andoni, and apparently forming part of the Lion River, connect with the Okavango. There is no salt in the Etosha Pan, but salt forms in some smaller pans on the flats to the west of the pan at a considerably higher level; the salt is derived from drainage from the western hills.

Economic Considerations.

The actual immediate results of damming up the Cunene at the cataracts and turning the water into the Etosha Pan will be purely for the benefit of the natives of Ovamboland; their country will be re-watered as of old, and it will accommodate the natural increase for an indefinite time. With the area that will be restored to fertility between the Etosha Pan and the Okavango River, I will deal in the section referring to White Settlement. I assume that it is a wise policy to help an industrious, virile nation like the Ovambos, if only from the fact that they constitute a valuable supply of native labour. The country is against White settlement, and the Ovambos are perfectly happy if left to themselves as they now are. If nothing is done along the lines I have sug-

gested, Ovamboland will dry up, and then where shall we find room to settle 150,000 natives with a very definite claim to be allowed to win their daily bread? In 1915-16 there was a famine, and in spite of all the Government could do, thousands died. Hundreds struggled along the road to Tsumeb in search of work and food, and perished by the way; all over the flats one still sees their skeletons, and even close to Tsumeb one sees the white skulls in the bush. The conditions that bring about famines are increasing.

Although, therefore, there are no settlement schemes connected with the western portion of the Kalahari scheme, there are other benefits to be derived from it. The principal one is that there will be put a stop to the creeping of desert conditions into the area forming the collecting ground for the head-streams of the Cunene, Okavango, Chobe, Zambesi and the Congo, and the restoration of Ovamboland as a source of supply for these rivers.

The South-West Protectorate is bordered on the east by the Kalahari; on the north by the Etosha Pan, and the waterless flats surrounding it; and on the west by the sea, chilled by the Benguella Current, and the coast strip of the most hopeless desert of shifting sand-dunes, the Namib. On the south, Namaqualand presented an equally dreary prospect. Where can a country so situated procure an adequate supply of atmospheric moisture to satisfy its wants? As it is, a large portion of the Protectorate is little better than an ash-heap during most of the year. If we want this great country, bigger than the Cape Province, bordering on the Union, to be occupied with a good class of settlers, we must give them reasonable conditions of life. If the Etosha Pan is filled up something in that direction will be done. To put it concretely: the air over the sea may be supposed to be saturated with moisture, and because of the Benguella Current its temperature is below that of the land, let us say, 40 degrees Fahrenheit. When the air from the sea is blown over the land, whose temperature is, say, 60 degrees, it becomes warmed, and so far from yielding moisture in the form of rain to the land, the cold air, now warmed, asks for more moisture to satisfy itself. If, on the other hand, the

air over the water in the Etosha Pan, at a temperature of, say, 80 degrees, were to be blown over the land in the Protectorate at a temperature of 60 degrees, the warm air, now cooled, would be unable to hold so much moisture, and rain would fall. That, somewhat crudely put, is the effect that filing up the Etosha Pan will have on the Protectorate.

At present we do not know what there is in the centre of the Etosha; two expeditions have started to cross the main pan, but they have never been heard of since, the explanation being, it is supposed, that in the middle there is boggy ground, and that the crust of hard clay over it must have suddenly given way, engulfing the whole caravan, men, oxen and wagon. At any rate, there is no free water, and the surface acts as a heater, drying the air.

The Site of the Cunene Weir.

As far as I can gather there are two methods of turning the Cunene into its old flood-channels: one being a more or less temporary arrangement of piles driven into the bed of the river, with branches and rubble filled in between; the other is of building a masonry dam. The first method, if adopted, would necessarily have to be applied to the river a considerable distance above the cataracts, and the advantages claimed for it are that it would be cheaper than the other method, and in addition, by taking out the water so high up, it would enable the scheme to provide the Portuguese with an irrigation canal in their own country, and so, in a way, compensate them; further, should an exceptionally high flood occur, the weir would be washed away, and less damage would be done to the surrounding country than if all the water were to be turned into the plain. As for compensation, I think a more satisfactory arrangement could be arrived at with the Portuguese, who, of course, have to be consulted, and who have every right to the greatest consideration; a question like this should not be allowed to interfere with the scheme being carried out in the way most advantageous for all parties. In regard to the disastrous flooding of the country, were a masonry dam to be built, spillways would naturally be provided, and they would be so

constructed that the water of an excessive flood would be carried away. As a matter of fact, however, the gradient of the Cunene River is so exceedingly small that if the weir were to be constructed at one of the cataracts, the water would be banked up for scores of miles above, and all the outlets would receive flood water. The natural site for the masonry dam is some six or seven miles above the small cataracts, where the river runs through a rocky gorge. The maximum height of the flood-level, indicated by dirt lines on the rocks, if forty feet; in other words, the river has risen at some time forty feet above its dry season level and no more, any water over and above that required to fill the river up to forty feet has been discharged into the spill-ways. The river is wearing away the cataracts so rapidly that at the time when the flood reached forty feet, the bottom was higher than at present. There may be sites suitable for the dam at the small cataracts, where the wall would not have to be so high, but there would be trouble with the sides here. If one went down as far as the Cambele and Rua Cana cataracts, one would be too far below the level of the Ovamboland plain for a dam to be of any use. I may explain that when the Germans drew up their agreement with the Portuguese about the border, a line was drawn due east from the "cataracts"; the Portuguese claim that the Rua Cana, or Great, Cataract was meant, but the Germans learnt, through their missionaries, of the smaller cataracts higher up, and claimed all the country up to a line drawn east from these, thus gaining six miles of territory all along the border. The matter is still open, and the six miles in dispute is regarded as neutral territory, and is administered by a Portuguese and an English resident conjointly.

A great deal has been made of the loss of riparian rights to the people living in the country below the proposed weir on the Cunene, and some have gone so far as to state that the question of compensating these would involve so much expense that the scheme would be ruled out on that ground alone. The answer to that is that there are no people living below the cataracts right away to the sea, nor are there ever likely to be. If, for argument's sake, it were conceded that

some mad people might be moved to take up their habitation in this terrible country, there are sufficient tributaries flowing in from the Kaokoveld and from the hills on the Angola side to make the loss of water unnoticeable. I was privileged to read Major C. N. Manning's report on his expedition into the Kaokoveld, which is the only description of this part of the world extant, since the German map is so inaccurate here as to show that no one had actually been along the Cunene in these regions. The only harm the weir can do is to enable freebooters to skip across the border more easily, but as they so do under present circumstances, no very great mischief can accrue.

In regard to the channels that would take the water to the Etosha Pan, no very great work will have to be done with them. They have naturally become sanded up since the normal flow has been stopped, but when this is restored, they will clear themselves. No artificial dredging should be resorted to, since the whole ground water of the lower Ovamboland plain has to be restored; it will take two or three years' floods to make good what has been lost since the time of the original diversion, and only when the water table has been restored will the floods reach the Etosha. The sand in the beds of the spill-ways will thus hold up the water for some time, and will enable it to soak sideways into the land, and bring the country back to normal fertility. It is very remarkable that with practically no drainage, there is no brak in the Ovamboland plain; no salts of any kind effloresce on the surface, nor are there any salts in the Etosha Pan. The salt pans on the west of the pan have obtained their salt from the drainage from the hills on the west of the plain, and in no way interfere with the general nature of the plain. I would emphasize this fact, as it has been stated that one result of my scheme would be to turn the whole of the north of the Protectorate into a salt morass. It is true that the peculiar nature of the ground allows the growth of only special plants adapted to the conditions; I do not think that the soil will ever be suitable for growing the ordinary farm crops, but the Mahonga grows freely, and as that is what the natives live on and do well on, I do not think we need worry. At any rate, I have never considered this portion of the

scheme as suitable for White settlement; it is required to strengthen the Kalahari part, where, as I shall show, there are unlimited areas suitable for settlement. The two halves cannot be considered apart, for, were the Kalahari portion to alone carried out and the Ovamboland plain left to dry up, the rivers would diminish, the climate would become still more arid, and life in the Kalahari would become insupportable. If the Ovamboland portion is completed, the rivers, the Cunene, the Okavango and the Zambesi, will be reinforced at their sources, rain-laden clouds will blow from Ovamboland to the Kalahari, and refresh the land where the irrigation canals cannot reach, and the whole Kalahari will become a reasonably habitable country. The Kalahari restored to fertility, the territories adjoining will be benefited, and so on, in ever-widening circles, till the whole of South Africa becomes a land where seasons can be depended upon to bring forth their appropriate harvests, and the recurring droughts are forgotten.

Relative Heights.

I have used for the purposes of the sketch map an excellent Portuguese map of Angola, published by the Commissao de Cartographia; on this map the height of Humbe is given as 1,070 metres, and on the Okavango, just above the border, the height of Menongue is given as 1,050 metres. On the German Kriegskarte the height of the Etosha Pan is given as 1,050 metres, or 3,445 feet. I made the Etosha Pan by barometer reading based on Tsumeb as 1,064 metres, or 3,490 feet. The Union war map gives two heights for the Etosha Pan, 3,444 feet for the western half and 3,346 for the eastern. I should like to believe that my reading is the correct one, being intermediate between the Cunene and the Okavango levels, but there is too great an element of doubt in these barometric readings to allow one to be at all sure. I took hourly readings throughout my stay in Ovamboland, and constructed curves from the results. I found that the barometer rose steadily till between 9 and 10 o'clock; then there was a steady fall till between 5 and 6 o'clock, after which the barometer rose again. The difference was more than one-tenth of an inch, and was equivalent to a difference in eleva-

tion of 150 feet. That is to say, if one took the reading at 10 o'clock, the height might be, say, 3,500 feet; at five o'clock the same place would be 3,650 feet above sea-level. With the curves plotted, one could allow for this difference, but it often happened that a thunderstorm came along and upset the barometer. At Tsintsabis, for instance, a storm came and the barometer showed a deep, level depression from half-past three in the afternoon till half-past seven, and the reading, if it were simply taken as the normal reading, would make Tsintsabis 200 feet above Namutoni, whereas the current in the river showed that there was scarcely any difference in level between the two places. This may possibly explain the difference in height given on the Union war map for different parts of the Etosha Pan; the pan is as level as a sheet of water all over, and there is certainly not a difference of 98 feet between the two sides. In regard to the relative heights of the Cunene and the Okavango, the Portuguese heights show that the Okavango River is considerably below the Cunene, which is borne out by the fact that the Cunene still pours over into Ovamboland, whereas the Okavango has ceased to do so. Franz Seiner, in his account of a journey into the Omaheke, gives the height of the mouth of the Omatako River where it debouches into the Okavango just above Dirico, as 1,075 metres; Seiner was wrong to the extent of 21 metres in his height of Grootfontein, and his figures for the Omatako are possibly equally wrong. When I went into Ovamboland the rains had not started, and I obtained fairly consistent results with the barometer, but on my return in the rainy season nothing seemed to agree; Namutoni, for instance, had apparently gone up 100 feet, and for six consecutive days the barometer recorded this difference as against the previous set of readings. Seiner's figures for further up the river must also be wrong; for instance, where the side-stream flows out of the main channel to Gesamas, Seiner has a height of 1,127, or 52 metres above the embouchure into the Okavango. Now the water of the Okavango could not bank up 52 metres, or 170 feet, yet I had the evidence of white people who had seen the Okavango water flowing into the Omatako; I had most definite Bushman evidence that the Ovambo flood of 1917 came by way of

Gasamas; I myself saw the flood channel coming into the Ovambo River; and finally, there are the full grown fish that had come from the Okavango, which were caught at Tsintsabis when the flood subsided. As the country along the Ovambo is flat, sand country which absorbs the rain water, the flood cannot have come from local thunderstorms.

According to the Rev. Father Gotthardt, the Missionary at Andara, the level of the Okavango in flood is six feet above that of the channel of the Omatako; only in exceptionally high floods, therefore, can the water find its way now to the Ovambo. Father Gotthart was at the junction of the Omatako and the Okavango in May, 1909, the time of the great flood in the Omatako basin; he writes: "I followed the Omatako River from a point, which on the German maps is marked as Numkaub (where the Gasamas oshana meets the Omatako, about 70 miles from the Okavango confluence) downwards to the Okavango. In that year almost the whole channel of the river was in flood, or more exactly, filled with water. A regular current could not be observed, the water at some points flowing back, at other forwards, and at other points not flowing at all."

Such evidence appears to me to be of more value than that obtained from barometer or boiling-point thermometer, both of which are subject to atmospheric disturbances that are often of very local occurence. My own impression of the Omaheke, or Gab,* as the Bushmen call it, is that it is a level plain with a small fall towards the south-east, and that consequently that portion of the Omatako that lies in it, from Gasamas to the mouth, has no fall worth mentioning. It is impossible to travel in the Omaheke during the dry season, and as the rains only began when I was returning, I was unable to do much in the way of personal observation, but at Kambonde's Vley the barometer traversed exactly the same points at it had been doing at Ondongua; I believe I am right, therefore, in saying that there is not a foot height's difference between these places, the sand country between, the true Omaheke being about forty feet above them.

* The only way for Europeans to pronounce this word, is to pull a stiff cork out of a bottle.

I have to thank the Administrator of the South-West Protectorate, Sir Howard Gorges, K.C.M.G., for allowing me to go into Ovamboland, which is beyond the police zone and is rightly closed to white men; every facility was given me for travelling where I wished, and the Military Magistrates and officers of the Military Constabulary gave me every assistance. It was, however, in Ovamboland that my principal work lay, and here the Resident Commissioner, Major C. N. Manning, together with Lieut. C. H. Hahn, not only saw to my welfare and arranged my transport, but placed at my disposal all the information that they had acquired in their travels.

The Okavango.

The Okavango is a perennial river flowing in a channel which it has cut deep in the Omaheke, or Ovamboland plain. The average width of the stream is from 150 to 250 yards, with a flood-plain bordering it of from one to three miles breadth and more. This flood-plain is limited everywhere by high banks, which Father Gotthardt, whose description I am following, states are from 150 to 250 feet high, but which I believe to be an over-estimate; the height is certainly very much less near the Portuguese border. Sometimes these heights come up to the banks of the river, when the plain disappears. The banks of the river are of clay or rock, while the base of the heights is everywhere of limestone. Every year, in January or February, sometimes even in December, the water in the Okavango begins to rise. The highest point at Andara is reached ordinarily at the end of March or the beginning of April. Further down the river it is later. Streitwolf, in his book on the Caprivi Zipfel, states that the highest point of the floods is reached in the lower course of the river in July and August; the explanation of the peculiar time of the floods is that, above the Andara rapids the Okavango flows in a valley with a very slight fall, and the swollen waters have to fill all the wide flood-plains covered with forest and grass, before they can come down. There is another reason, also, that the great swamps below the Popa Falls are growing larger every year; these are from 20 to 35 miles broad, so that the flood-plains

above the falls are trifling in comparison. Above the falls, the fall of the river is about one foot in the mile, or 1 : 5,000; in the region of the rapids, according to Father Gotthardt, 5 feet to the mile, or 1 : 1,000. The height of the Popa Falls is about ten feet. Below the falls, the river breaks up into a number of small channels, which are at first confined between the high walls of the extension of the Ovamboland plain, called here the Mabula Veld, on the north, and the Kung Veld, on the south.

When, however, the river emerges on to the bed of the old Ngami Lake, a sort of delta is formed, and the river splits up into several branches. The most southerly branch is called the Teoghe, or Tauche; this is the branch along which the principal swamps are, and is also the one that used to supply Lake Ngami. Dotted over the swamps are indescribably pretty islands, full of palms and other forms of tropical vegetation. Just on the border of the swamps, about forty miles from Lake Ngami, there is a large native village called Tsao; it is the capital of the Batawana people, and there are also the quarters of the Resident Magistrate and a fairly large police-camp. On the river itself live the peculiar race of the Makoba, who are virtually slaves to the Batawana. Between the lake and Andara there are two distinct tribes, one a light coloured ordinary South African Bantu type, the Bayeye, and a quite black tribe, the Mampukushu, who are evidently Ovambos. The once famous Lake Ngami is now a vast reed marsh, no large expense of water being visible from the shores. The climate is extremely enervating in summer, and the marshes are the source of malaria and blackwater fever. The opening up of the former channel to the Makarikari and its outlet to the south, will cause a sufficiently strong current in the Teoghe region to limit the flow to one definite course, and to do away with much of the marshland. Two central channels, the Siroe and the Poro, strike across the Ngami depression, and join at the south-east side as the Tamalukan, or Thamalakane River.

This last river used to lead down from the Chobe to Lage Ngami, and Chapman in 1853 saw the Chobe flowing towards Lake Ngami, that is, southwards. According to

some travellers, the obstruction was caused by the natives setting adrift their frail reed-rafts after they had finished with them, and in course of years these jammed, became matted together with weeds, and stopped the flow of the river. From my own observations of similar rivers, I should say that the process would have been more probably as follows: after a drought, the river comes down, carrying in its forefoot a great tangle of boughs and wreckage from the forests. This ploughs up the sandy bed of the river, and turns the stream into a mass of quicksand, which flows slowly, and is easily stopped by any impediment, such as the narrowing of the stream bed. Such an obstruction has stopped the flow of the Otjimpolo River, and the whole of Ovamboland is full of similar examples. Mr. R. S. Fairbridge writes that when lying in hospital at Umtali, the late Mr. Swithin Wood told him of the obstruction which he had seen, and which, with a little labour, could be cut through, and the southward flow of the waters facilitated. Mr. M. Kays, of Ghansis, near Lake Ngami, actually proposed to the chief Mathibi, the chief of the Batawana tribe, that he should lend him a couple of hundred of his Makoba subjects and the necessary canoes, for the purpose of opening up the closed channels of the Okavango River, to enable the water to flow once more to the Ngami, which is now but a swamp. The chief was most enthusiastic about the whole scheme, but unfortunately, like the Spaniard, it was "to-morrow."

The Selinda, Magwagena, or No channel now short-circuits the Okavango waters past the channels leading into the old Ngami basin. There is a good deal of discrepancy about this in the various accounts. Mr. H. V. Eason, who was there in 1908, writes that the Okavango water only comes down this channel once in ten years. King Lewanika had told Major St. Hill Gibbons of this connection, which he calls the Mag'wekana—with a click after the "g"—and travelled south till he struck it. "For the first few days the bed was clearly cut, and about 100 yards wide, but at that time perfectly dry. I wondered whether this was not the original bed of the Okavango, and whether that river had not at one time been part of the Zambesi system. On April 14th, the

bed having become much wider and less well defined, we saw in front of us numerous water-fowl flitting about. My chiefs grunted their disapprobation on seeing this, informed me that the water was coming, and a short distance further we were ankle deep. The overflow from the Okavango had commenced, and since the definite bed of the river had now disappeared, the whole country to right and left was inundated. For three and a half days I had to wade knee-deep, camping wherever I could find a comparatively dry spot. I was just a week too late, but my guides assured me that another week would have meant water to the shoulder; in fact, in one or two places it was so already. The natives told me that the overflow continued for a couple of months, when the inundations gradually drained off into the Chobe, and the land became dry once more." Mr. Percy Reid states that the Selinda is commonly used by natives as a water-way between the Chobe and the Ngami regions. At any rate, this is a leak, which, if we wish to fill up the Makarikari, must be stopped, and it may be necessary to tackle it independently of the Chobe weir.

The Botletle or Zouga River joins the Tamalukan at right angles; it is a wide, cool stretch of water, flowing silently onward to its grave in the desert. The recent flools along the Okavango have caused it to run with sufficient force for its waters to reach the Makarikari as of old, leaving Lake Ngami on one side. The Kalahari sand is always blowing into the channel, and it is the chief object in increasing the volume of the Okavango, by throwing in the water of the Cunene, that the current should be enabled to overcome this obstruction; otherwise, if nature is left to herself, the Botletle will become sanded up, and the whole of this area will become waterless.

The Site of the Chobe Weir.

In my original proposal, I suggested that the most suitable site for the Chobe weir was at Ngoma, about thirty miles from the Zambesi confluence; the reason for this was, that on the east there are high, rocky walls bordering the Ngami depression, and the flood-plain of the Chobe and Zambesi here rises somewhat. Mr. Ivor Lance, of Senanga, Northern

Photo. by] PLATE IX. Tchitchib, on the Camka (Lion) River, Ovamboland. [R. Schlange Tsumeb.

Photo. by] **PLATE X. Nandonga Water-hole.** [R. Schlange, Tsumeb.

The water falls 30 feet in the dry season.

Rhodesia, writes, April, 1918: "At the present moment the spot for the proposed weir at the Chobe mouth is twenty feet under water, and the whole of the surrounding country is a vast sheet of water for hundreds of square miles; also the Zambesi, including the Barotse Valley, is all under water; the flood-water this year is within ten feet of my door, and the whole country is like the sea. Now all this flood-water goes down the Zambesi into the sea, but how is it that a certain proportion of it does not find its way into the Okavango and then into Lake Ngami?" The answer is, that the old channels are sanded up, and a flood, which only lasts a short time, is not able to clear out channels extending over hundreds of miles. As a matter of fact, the water apparently did work its way down into the Molopo, and spread out into a great lake at Abiquas Puts, north of the Orange River. When the weir is in position, the level of the water will be permanently raised, and the constant pressure will gradually clear away the sand-banks; in addition, the Okavango, reinforced by the Cunene water, will tend to rush straight down to the lowest point, the Makarikari, and not, as at present with its smaller flow, become entangled in the marshes, so that a scouring action will be possible. Mr. Eason, who lived in this district as Magistrate, writes that the only place for a dam is about five miles above the junction with the Zambesi, at the Nduala Rapids, which are formed by the same bar of rock as that which crosses the Zambesi at the Mambova Rapids; both rivers would have to be blocked. I do not, however, propose to build a masonry dam; all that is needful at present is a weir built of piles and filled in with rubble and branches. If this will last only a few years, it will allow the Okavango to scout out its channel, the old courses of the Tamalukan and Botletle will be revived, and the Chobe will then tend to flow south instead of north, as at present. When the condition of the rivers has become more or less settled, then we can see what permanent works are necessary to perpetuate this diversion. The enormous floods of 1918 are not likely to be repeated.

Albert Schmidt, in "Eine Talsperre im Kwandotal," proposed a scheme for weiring up the Chobe between the

Sebuba Falls and Ngoma, placing a regulating weir near Linyanti, further up; such a plan is certainly advantageous, as it relieves the lower weir of much of the pressure. Schmidt's scheme was intended to provide a sufficient fall at the lower weir to drive turbines to supply electricity to the railway which was proposed, joining the South-West Protectorate with Rhodesia, but his levels were altogether exaggerated.

In 1902 there was suggested a vast irrigation scheme for the Kalahari, from water taken out of the Zambesi River; when the Victoria Falls Power Company obtained the rights over the Zambesi water, the scheme was dropped. It may be of interest to state what the Falls Power Company exactly contemplate.

The Victoria Falls.

Mr. W. Carter, in the Rhodesian Munitions and Resources Committee Report, writes of the Victoria Falls that statements had been made that the river at this point was 800 to 1,000 yards wide, 80 to 90 feet deep, and had an average velocity of about four miles an hour. It was from unreliable data of this nature that the immensity of the power to be derived from the Falls was in part deduced, and calculations based on these figures would give about one hundred times more power available than can be arrived at from actual measurements during the period mentioned above. The volume of water which might be utilised during the flood season is not taken into consideration except in connection with the position of a power station.

Several ineffectual attempts were made to get a line across the river at the point mentioned, but the materials available were unsuitable, and the width of the river was eventually arrived at by triangulation, which gave a result of 373 yards. Three sets of soundings, consisting of forty soundings each, were taken across the river at one hundred yards intervals up and down the stream; the greatest depth obtained being 26 feet 3 ins., and the mean of the lot being 18 feet. Sighting marks were then laid out on the bank 200 yards apart, and numerous floats with their current boards

suspended at varying depths were checked over their distance at various points in the width of the river; this gave a mean velocity of seven hundred yards an hour, or a volume of seven hundred and four thousand nine hundred and seventy cubic feet per minuts. As there are no affluents to the river below this point, the Maramba being merely a backwater, this can be taken as the volume which actually passed over the lip of the Falls. The width of the Falls across the crest is about one mile eight chains, and is divided at follows: North-Eastern Fall, Rainbow Fall, Main Fall and Devil's Cataract, the greatest fall in the clear being 360 feet; measurement taken with weighted line. The Maramba river, previously referred to, but which is actually a backwater, is a likely place to tap the river, and if the water is conveyed from this point to a power station in the gorge by means of steel pipe lines, an additional 20 feet of head could be secured.

Taking three hundred and sixty feet as the head due to the actual fall, and adding the twenty feet for the drop from the intake to the crest of the Falls, the total head available is three hundred and seventy feet, assuming the turbines are kept ten feet above the water in the canyon, and disregarding pipe line friction, but the question of high water in the river has to be considered. At the point where the soundings were taken the rise during flood times was nine feet, and this corresponds to a rise of forty-four feet in the canyon, giving a ratio of about five, which though not true at all heights, is sufficiently accurate. It is more than probable that, in an excessively rainy season, the river would rise eleven feet, giving a rise of fifty-five feet in the canyon. Taking the position of the turbine station as above this flood mark, it would reduce the available head to three hundred and fifteen feet. Assuming an efficiency of 85 per cent., and a further loss for pipe line friction the power available is equivalent to about 263,000 kilowatts if the total volume of water as above estimated could be utilised. Although the amount of power available from the Victoria Falls, during the period of the year when the river is low, is nothing like so great as has been widely imagined, the dormant power is

enormous, and no doubt a large part of it will be utilised at some future date.

From a commercial point of view there is no early prospect of generating power on a large scale. To attempt to supply power requirements throughout Rhodesia would involve many leads over long distances for a comparatively limited demand. Transmission to the Rand is, with present knowledge, out of the question, there being no prospect of successful competition with the cost at which power can be generated in proximity to the collieries there, and electrification of the railways of Rhodesia is so fart outside the range of probability that the question is not worth discussion at present. With modern progress and the great advance in electro-chemical industries during recent years it can easily be conceived, however, that a large industrial centre may gradually develop in the future. It will be seen that the flood waters are not required, and therefore the weiring up of the Chobe will not interfere with these projects; further, the restoring of the conditions in the region of the head-waters of the Zambesi will give a fuller and more constant flow in normal times, and so the Kalahari scheme will be distinctly of benefit to the Victoria Falls Power Company.

Lake Ngami is an expansion in the system of inter-communicating canals of the Okavango Delta, and lies under the eastern bank of its former basin. Oswell discovered the lake on August 1st, 1849, but in editing Livingstone's book, he deleted all references to himself; in the list of illustrations, however, which escaped him, the title reads: "Lake Ngami, discovered by Oswell, Murray and Livingstone." The picture shows only Livingstone and his wife, with three children, the youngest of whom had been born on the Botletle a few weeks previously. Livingstone described the lake as being 60 miles wide, and from the writings of Livingstone, Chapman, Baines, and other travellers of that time, the general impression has arisen that Lake Ngami is a respectable sheet of water. In 1897 Passarge found that the water had entirely disappeared, and its place taken by a brown expanse of reeds, between the roots of which the traveller sinks into the treacherous mud. This was the condition of

Lake Kumado in the south of the Makarikari depression in Chapman's time, 1852, and here the lake has entirely disappeared, as Ngami will shortly if nothing is done to prevent it.

Livingstone recognised that Ngami was once the site of a vast lake; he came to this conclusion from the prevalence of fresh-water shells in the limestone layers that appear underneath the sand. He it was, too, who first explained the climatic changes in South Africa as due to the draining of this lake by the Zambesi. Livingstone called it "a breaking through" of the Zambesi, but I have ascribed it to the head-stream erosion of the river. In view of the recent earthquake at New Langenburg, it is quite possible that the fissure was opened by earthquake shocks, in which case the early Portuguese Missionaries may have been right when they said that in their time the Zambesi began below the basalts of the Falls and the Batoka Gorge. The limits of the two great Kalahari Lakes are shown in the map which I have drawn from that by C. Jurish, which accompanies Passarge's work on the Kalahari. The limits of the Makarikari are indefinite on the north, for here we have the Gwai Poort, which is the old valley of the Loangwe, before the Zambesi trenched across it. There has been doubt expressed as to whether, if the Makarikari were to be filled up again, the water would not escape by the Gwai Poort, but Chapman is positive that there is a distinct water-shed, separating the two areas.

The Kwando, Linyanti, or Chobe River, the last is the name appearing on Oswell's original map, and should stand, like the Okavango, enters the Ngami depression by a sort of delta, receiving an important tributary, the Selinda, from the Okavango, which is short-circuiting the water past Lake Ngami, and then expands into a vast swamp, through which the water filters into the Zambesi. Livingstone happened to be on the borders of this swamp in 1860, and describes how, after a period of drought, the natives were burning the reeds in order to drive out the elephants that fed in the swamps. The chief, Makompa, with his men lying in wait, had killed five elephants and three buffaloes with their spears, as well as wounding several others which escaped. With man

helping to clear away the obstructions, the draining of Ngami by the Zambesi became accelerated. Hundreds of similar examples might be quoted from the Cape Province, many of which I have seen myself; a swamp, either of reeds or palmiet, is burnt in the dry season, and in a very few years there is produced a dry valley, down which the flood waters rush during the rains, leaving no portion held in reserve in the swamp, that, like a sponge, had previously retained it.

The Chobe Swamp has been driven away from the eastern side of the Ngami depression here, but a portion of the Chobe water, together with some from the Okavango, reaches the far side to form the Mababe Swamp. The north-eastern continuation of this is the Komane River, which apparently no longer connects with the Zambesi, if it exists at all at the present day as a river-bed. It was crossed by Chapman in 1852, and has not been seen since.

The Zambesi enters the Ngami depression by the Mpandwe Falls, and leaves it at Kasungula, where the Chobe joins the Zambesi, some 50 miles above the Victoria Falls. Between these two points the river follows the north-eastern border of the depression. When the lip of the Victoria Falls was a few feet higher, the whole of the Ngami depression was a vast lake, 300 miles long, from south-west to north-east, and 100 miles broad, having the appearance of a rift-valley lake, like Nyasa and Tanganyika, which are 350 and 235 miles long respectively. At a still earlier stage, the Victoria Falls formed an unsurmountable barrier for the Zambesi, and its waters went into and filled up the entire Ngami depression. This lake was tapped by the Zambesi below the Falls, eating back by head-stream erosion, just as Tanganyika has been tapped by the Lukuga in quite recent times; in a few centuries Tanganyika will be drained dry by the Lukuga, and its basin will present the same appearance as the Ngami depression now does.

Livingstone's description of the country is as follows, ("Missionary Travels," page 527):—

The level of the lower portion of the Lekone is about 200 feet above the Zambesi at the Falls, and considerably more than the altitude of Linyanti; consequently, when the river

flowed along this ancient bed, instead of through the rent, the whole country between this and the ridge beyond Andara westwards; Lake Ngami and the Zouga (Botletle) southwards; and eastwards beyond Nchokotsa, was one large freshwater lake.........The whole of this is paved with a bed of tufa, more or less soft, according as it is covered with soil or left exposed to atmospheric influences. Wherever ant-eaters make deep holes in this ancient bottom, fresh-water shells are thrown out, identical with those now existing in Lake Ngami and the Zambesi.........The whole of these lakes was let out by means of cracks or fissures made in the subtending sides by the upheaval of the country. The fissure made at the Victoria Falls let out the water of this great valley, and left a small patch in what was probably its deepest valley, now called Ngami.........The Congo, also, finds its way to the sea through a narrow channel.

The greater Ngami found an outlet southwards down the Botletle to the Makarikari, the two sheets of water being thus connected, like the Albert and Albert Edward Nyanzas, by the Semliki River. Livingstone, who approached the Makarikari in 1849 by way of the Makoko River, states ("Missionary Travels," page 61) that the Makoko below Lotlakani spreads out into a very large lake, of which Ngami formed a very small part. According to Chapman, who crossed the Ntwetwe Pan several times, and who was on the eastern side of the depression in 1854, the banks on the east are abrupt and steep. The older Bushmen told him that some thirty or forty years ago the lake never dried up, and abounded with hippopotamus, crocodiles and fish. Suddenly, they said, the waters from Lake Ngami ceased to flow; the lake dried up, and the dead fish and animals were devoured by vultures. In Chapman's time the vast expanse of the Soa Pan was nothing but a barren plain, level as a plank floor, and covered with a white, saline incrustation. This level plain became inundated during some months of the year, assuming then a very grand appearance, though only twelve to eighteen inches deep.*

Aurel Schultz (1897) states that the natural outlet for Makarikari is through the Macloutsie Poort, down the Shashi River, and so to the Limpopo, and this view is expressed in Sir Charles Warren's official map, Blue Book, August, 1885,

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* J. Chapman, "Travels," London, 1868, vol I., page 242.

but Chapman (loc. cit., page 257), who was in this angle of the depression, states that there is a range of hills shutting in the view, and directed S.W.-N.E. In the same way other travellers maintain that the Gwaï Poort is the natural outlet, and that if the depression were to be filled up the water would flow down the Gwai River, and so into the Zambesi below the Falls. Chapman discovered the Gwai River, and he distinctly states that there is a big rise from the Makarikari to the water-shed, and the fact that the Makarikari was a lake at one time rather discounts this view; besides the whole drainage on the east of the depression is towards the pans, as shown by the Shua or Nata River. The old hunters' road from the South to Pandamatenka and Kasungula passes across this Gwai Poort, and Hodson shows the drainage towards the pan in his route map of this region. Livingstone recognised that the original outlet was on the south, and he calls it the old river that flowed through the Kalahari and joined the Orange River.

Before the Zambesi drained the Ngami basin, the Kafue was not diverted into its present course, but made straight for the Ngami depression, instead of, as at present, turning abruptly at right angles and joining the Zambesi below the Falls. Unless we adopt the explanation I have given, both the Kafue and the Loangwe would appear to have flowed *up* the main basin of the Zambesi instead of down, as in all normal river systems.

The wear and tear of the rock-lip of the Victoria Falls is so tremendous that every year the level is sinking, and more water is being drawn from the Chobe-Okavango system. Livingstone noticed evident deepening of the river-bed above Sesheke ("Missionary Travels," page 216). The Chobe Swamp will soon be drained, though in May, 1918, owing to unprecedented rains, it was a vast inland sea; the old channels to the Ngami are sanded up, and the water cannot escape fast enough over the Falls. What is to be feared is that after such a flood as has occurred this year, the water from the Okavango will find a straight course by the Selinda branch to the Zambesi, and the Ngami Lake will disappear as completely as the Kumado Lake in the Makarikari.

To complete the preservation of what is left of the river system of the Kalahari, and to prevent desert conditions from spreading beyond the Kalahari, as they obviously are at the present day, it will be necessary to weir up the Chobe River, between the swamps and its confluence with the Zambesi, to prevent the water that is turned into the system by the proposed weir on the Cunene River from escaping down the Zambesi, and increasing, perhaps, the beauty of Mosioatunya, as the natives call the Victoria Falls, but doing no good to the country. The site for this weir is about thirty miles from the junction of the Chobe with the Zambesi, three miles east of the village of Ngoma; here there is high ground on both sides of the river. Lower down, at the Sebuba Rapids, seven miles from the confluence, there is a bar of hard rock crossing the river, but there is only high ground on the south; on the north there is a dead level plain, flooded by the Zambesi. The same bar of rock crosses the Zambesi and forms the Mambova Rapids. The idea of the weir is not to form an absolute barrier to the outflow of the waters, but to provide an impediment, which will make the water pond up against it, and allow the water from the Okavango, coming straight to the Ngami, to clear the old channels of the sand which now blocks their beds. The weir, in such tremendous floods as have occured this year, would be entirely submerged, but gradually, as the old channels are scoured out, the water would flow into the Makarikari, and the weir would become more of the nature of an unsubmerged wall.

To recreate the Greater Ngami in its entirety would mean the building of a barrage across the Zambesi, which is too big a scheme to advocate just at present; there are, also, too many interests involved, not the least of which are those of the natives who live in the Ngami depression; if the whole depression were to be flooded, these natives would be drowned out. As the Makarikari depression is 150 feet below the level of Lake Ngami, the proposed Chobe weir would cause a considerable expansion of the area of Lake Ngami, would turn the Mababe, Mashabe and Chobe Swamps into large lakes, and the overflow would go down the Botletle River and fill up the Makarikari basin. A sheet of water of this size, some

15,000 square miles in area, in the middle of the Kalahari, would turn this great thirst-land from being the source whence all the drought-producing hot winds originate, into an evaporating dish supplying rain clouds for the whole of South Africa; for moisture in the centre of a continent is not dissipated as on the sea-board, by winds that may blow the rain-laden clouds out to sea, but, as it is transpired by the leaves of the forest trees and the grass of the meadows, or evaporated from the surfaces of lakes, it ascends into the air and is precipitated as rain over the adjoining country, and the process is repeated in ever-widening circles. The converse is also true; a desert keeps the air hot and dry, devastating hot winds blow from these regions, and scorch up the adjoining lands. In South Africa, whether in the Karroo or the coastal plains on the west, one sees after rain the original vegetation spring up, green and tender, among the hardy, permanent bushes; this "opslag," as the Boers call it, is very short-lived, for in a few days the hot winds come and wither it up. It is a fact, too, that many of the severest droughts in South Africa are not due to deficiency of rain-fall, but occur because between the falls of rain the desert winds come and wring out of the soil every drop of moisture. As a case in point, I may mention the drought in the Eastern Province in 1913-1917. With quite a fair average rain-fall, the hot winds had so dried the soil that the run-off, after rain, was reduced to 4 per cent., 96 per cent. being absorbed in the ground, which had become as dry as ashes; in the latter half of 1917 the drought broke, and a succession of rains fell without the intervening periods of hot winds, and the run-off rose to 80 per cent., only 20 per cent. being required by the soil.

To revive the whole of the Proto-Orange system is no longer possible; it is more impossible than to revive the Proto-Congo system. South Africa stands at such an elevation above the sea, that the rivers quickly cut for themselves deep canyons. The Loangwe River, for instance, which was once on the Ngami level, now enters the Zambesi below the Victoria Falls, at a elevations of 774 feet, whereas Lake Ngami is 3,117 feet, and the Soa Pan 2954 feet above sea-level. Kasungula, at the confluence of the Chobe and

Zambesi, is about thirty feet below Ngami; the site I have indicated as suitable for a weir cannot be much more than 10 feet below Ngami, in fact, Chapman found the Chobe flowing up the Tamalukan towards Ngami in 1853.* Between the site for the weir and Kasungula there are the Sebuba Rapids. As we have taken the Soa Pan to have been on the course of the Central South African River, the Proto-Orange, the Zambesi must have cut downwards 2,161 feet since it captured the Loangwe. This seems a vast amount, but when one regards the gorges of double and treble the depth, cut by our small rivers in the Cape Province, through the coastal rampart, it does not seem so great after all.

The outlet of the Makarikari is to the south. Where the water will flow after this lake is filled up is uncertain. The country has not been surveyed, and in addition, sand has obscured the old river beds. The great river from the west is the Epukiro; it rises in the great knot of mountains near Windhuk. Further east it is known as the Eisib and Otjimbindwe, a Damara name meaning blood. It has also received the name of Wahlberg Spruit. after Professor Wahlberg, the naturalist, who was killed by an elephant here. The dry river-bed passes Rietfontein North; at Carolina Hof, 25 miles from the Bechuanaland border, there is a strong stream of underground water, from 5 to 6 feet below the surface, and this same water comes up 100 miles further east, where the Ghansis road crosses the valley. This is good evidence of a former flow of water above the ground, and there is no doubt that this river was at no very distant date an ordinary periodical river like any of the present Karroo rivers. The Otjimbindwe is joined on the south by the Okwa River, and the united valley goes northwards to open into the Makarikari depression. Mr. Kays, of Ghansis, states that Andersson travelled along the Okwa till he came to the vley marked on the maps as Andersson's Vley, which, however, is of doubtful existence. The Okwa then leads past Loklakane, thence to Selokolele, near Kanya, and so to the Molopo River at Mpaea-thutlwa. Judging from the number of vleys north and south of Lehututu, there is every reason to suppose that there

* "Chapman's Travels," 1868, vol I., page 184.

was another route that the water, when it did flow, sometimes took, thus leading it from the Otjimbindwe, or Epukiro, to the Nosob at Mier.

The Kaap Plateau drains into the Kalahari, by stream-beds of considerable size, though now dry. All these are directed to the north-west, and some of them connect with the central portion of the Molopo River. The present commencement of the Molopo near Mafeking is a stream that often flows, but the water does not get many miles west of the town; the river, after proceeding in a westerly course, turns north-west, then due west, and then due south. At this last bend I have placed the junction of the Proto-Orange with the present bed of the Molopo, as the most probable place, thus making the Molopo a tributary of this river above the bend; below this, the Molopo would be the bed of the original principal stream. According to the relief map in L. Schultze's book on Namaland and the Kalahari (1907), the main river may have joined the Nosob first, the Molopo entering it lower down. At any rate, the natural inclination of the land would lead the water in the direction I have stated, and the Makarikari Lake, if refilled, would not flow north or east through either the Gwai or Macloutsie Poorts. The Kalahari sand has obliterated the more northerly portion, just as the Saharan sand has obliterated the middle portion of the Igharghar.

On the west of the Kalahari we have the highlands of the coastal rampart, and these drain by several very large, dry rivers into a central channel, the Molopo; they all run in a south-easterly direction, and the chief one is the Nosob.

The Molopo River enters the Orange River below the great bar of granite at the Aughrabies Falls. The whole of the area under discussion, that is to say, the drainage area of the Proto-Orange, is a plateau inclined to the south-west, and we have assigned to it its natural outlet. This Proto-Orange has been beheaded; its head-streams have been diverted by the Zambesi, and the central portion has been bereft of its natural aliment, and has become a desert. Luckily, its southern affluents, the present Orange and Vaal Rivers, still have water in them, but the same process is

going on all around the basins of their head-streams, the coastal streams are eating back through the girdle of the coastal rampart, and every year more and more water is being hurried precipitously to the sea, instead of going the long journey across the continent, where it can do some good. How great a river this Proto-Orange was may be gathered from what is described by Dr. P. A. Wagner:—"Six miles south of the Upington-Keetmanshoop railway I found on a small island in the middle of the present dry channel, an extensive terrace of coarse river wash, 15 feet in thickness, with well rounded boulders up to 18 inches in diameter, the top of which is 35 feet above the river-bed."

In the Cape Province the rampart of dolerite-capped hills of the Karroo guard the inland waters, what little is left of them, the tough nature of the rock yielding very gradually to the agencies of weathering and erosion, but still the Great Fish River has eaten a great bite out of the inner drainage area. The dolerite-capped escarpment of the Karroo is a secondary watershed, and stands in the same relationship to the coast ranges, as the Batoka basalts of the Victoria Falls stand to Kirk and Melsetter Ranges. In the Transvaal, we see the Komati River stealing into the territory of the Vaal River; the Olifant's River draining inland as far as Pretoria, and the Limpopo River reaching back even to the outskirts of the Kalahari. Further north, the Sabi River has pierced the Melsetter barrier-range, and drains the whole country from Bulawayo to Salisbury; finally, the Zambesi sends back its tentacles almost to the West Coast. Every one of these rivers started originally at the coastal rampart, and has eaten back by head-stream erosion. The waters inside the barrier-ranges once flowed towards Central South Africa, and made the central depression a land of running rivers and of great fertility.

We cannot hope to bring all or any of these rivers back to their original courses, and to weir up the inland streams is simply to check their flow, and to give a further advantage to the vigorous coastal streams. We can, however, stop the further desiccation of the central portions of South Africa by building two weirs, one across the Cunene River, below

Kinga, and the other across the Selinda River, or better still, across the Chobe River, between the swamps and the Zambesi. The study of any good map of South Africa will show one how the steep, coastal rivers are stealing inland and draining the waters that flow towards the centre, so that the waters that once went to ferilise the plains are turned back and hurried uselessly to the sea. Not only are the courses of the rivers steeper on the seaward side of the mountain rampart, but owing to the fact that this intercepts the moisture-laden sea-breezes, there is more precipitation on the seaward side. If we could give more rain to the inland area we should equalise matters more nearly, and delay the invasion of the coastal streams indefinitely.

The scheme outlined here is a practicable one to give South Africa a greater general humidity, and is not an excessively expensive one. The two weirs across the Cunene and Chobe Rivers will cause the Etosha Pan to fill up, and Lake Ngami to cover much of its former area, making one great lake out of the present separated tracts of Ngami, the Mababe and Chobe Swamps; the overflow would fill the Makarikari depression, which, with the Gwai and Macloutsie extensions, covers an area of 15,000 square miles. There would be thus created a source of supply for rain-clouds, that would refresh the Kalahari and clothe its sand-hills with permanent pasture. The water transpired by the vegetation covering this great tract would ascend, and be precipitated throughout the area within the girdle of the coastal rampart; the condition of South Africa would be restored to that of some two or three hundred years back, when the Karroo was a flower-garden, supporting vast herds of game, and the present dry rivers ran throughout the year. Unless this is done, the central supply for our rain will dry up entirely; desert conditions will spread until South Africa will become a waste land like North Africa, and the fate of Cape Town and Pretoria will be that of Berenice and Taodeni. Such a future will not be fulfilled in our lifetime, nor in a century, but we can go back in this descent several hundred years in one step, by stopping up the leak while it is still mendable; we can preserve South Africa from the fate of North Africa, where the leak has become a rent, beyond our present skill in engineering of repair.

The deficiency of rain in South Africa.

As a convenient figure, we may take 10 inches of rain as being the addition required to make South Africa a fertile country all over. It would immensely help matters; along the south coast, where the rainfall is about 30 inches, it would become 40; not excessive. In the Karroo behind, 15 inches would become 25; an enormous improvement. In the Kalahari, from an average of 2 to 12 would allow of ranching on a very large scale indeed. This is a wrong way of looking at the matter, but as it has been quoted as showing the inefficiency of the Kalahari Scheme to relieve the state of affairs, it will be worth while to examine the figures on this assumption. I have left out the Ovamboland plain, as the evaporation from this will mostly go to reinforce the rainfall on the Angola Highlands.

Deficiency of rain, assuming that all of it must be supplied from the Kalahari lakes.

Area over which there is a deficiency of rain :—

1,000,000 sq. miles, or 27,561,600,000 sq. feet.

10 inches of rain over this would be :—

22,968,000,000,000 cubic feet.
say, 23 million million cubic feet.

To supply this we have the Okavango, Chobe and Cunene Rivers.

Okavango River :—

Average width, 200 yards, 600 feet.
Average depth, flood and dry season, 10 feet.
Rate of flow, 5 miles an hour.

Therefore in every hour there flows :—

600 x 10 x 5 x 5280 cubic feet of water, that is 158,400,000 cubic feet.

There are 8,760 hours in a year, therefore the annual flow of the river is: 1,387,584,000,000 cubic feet,
in round numbers, 1.4 million million cubic feet.

Flow of the Okavango River ...	1.4	million	cubic	feet.
Chobe River ...	.7	,,	,,	,,
Cunene River ...	.4	,,	,,	,,
	2.5	,,	,,	,,

This water will be conserved, and will circulate in the basin:—

1st	year's	supply,	2.5 million million cubic feet.
2nd	,,	,,	5.0
3rd	,,	,,	7.5
4th	,,	,,	10.0
5th	,,	,,	12.5
6th	,,	,,	15.0
7th	,,	,,	17.5
8th	,,	,,	20.0
9th	,,	,,	22.5

In the tenth year, therefore, there would be sufficient moisture evaporated from the Etosha Pan and the Makarikari Lake, together with the accumulated stock that had been previously impounded, to give the necessary 10 inches of rain, requiring 23 million million cubic feet of water. It may be argued that of the rain that results from the transpiration of moisture due to previous falls of rain, only part will fall within the drainage basin of the lakes. That is so, but what is lost in this way will be made good from sources outside the basin; rain clouds from the sea will blow over, and because of the favourable condition of the air over the lakes, precipitation will ensue. The losses and gains in this way may be taken as equalising themselves.

The calculation is not of much value, because, as a matter of fact, with a little additional moisture in the air over the interior, a very much larger rainfall will be induced. Quite half of our rain clouds drift away and carry their moisture out of the country because of the want of a small additional humidity. Pressure is reduced sufficiently to cause rain with, say, a 70 per cent. humidity, but if the air only holds 65 per cent., the rain-storm passes over to the north, or to the sea, where this requisite amount is available. The more droughty the country, the more the rain will shun it; the converse is

Photo. by] [the late J. W. F. Breijer.

PLATE XI. Hyphaena Palms, Ondonga.

Mopani Trees, near Kambonde's Vley.

PLATE XII. My trek into the Omaheke.
Chief Mandumi's waggon.

Kambonde's Vley.

true, the more moist the country is, the more will rain be attracted.

Evaporation Statistics.

The position, however, is much more serious. The rainfall in even the favourably situated parts of the interior is only one-third of the evaporation. This means that besides the water running to waste down the Cunene and Zambesi Rivers, the air is capable of drawing up at least twice as much as it supplies the land with. The evaporation is usually assumed to be some 60 inches, but most careful measurements made at Grahamstown in connection with the municipal water schemes showed figures of over 90 inches. This is the figure for Johannesburg, and I think it is more like the actual amount throughout the interior of the continent south of the Zambesi. From the edge of the high veld to the sea board I assume that the evaporation averages half this, namely 45 inches.

Area over which there is a deficiency of moisture in South Africa.

Area in sq. miles.	Rainfall. inches.	Evaporation. inches.	Deficiency of moisture. inches.
600,000	5	90	85
280,000	15	90	75
320,000	30	45	15

I cannot follow Mr. C. M. Stewart when he states that there are only 240,000 square miles with less than 20 inches; Schunke-Hollway gave 700,000 square miles. These under-estimates would be very much more favourable for my argument, but I believe the figures I have given represent more nearly the present-day conditions in South Africa.

Additional water required before the balance between rainfall and evaporation is reached.

600,000	sq. miles	require	117	million million	cubic feet.
280,000	,,	,,	48	,,	,,
320,000	,,	,,	11	,,	,,
1,200,000	,,	,,	176	,,	,,

I do not think that by any manipulation of figures one can reduce this by more than a third. The amount when translated into rainfall becomes 63 inches, more than anyone requires, but of course, rain only falls when there are barometric depressions. What the figures mean is that until this amount is provided South Africa will be going backwards, living on its capital; if it is supplied, then what is taken from the ground will be made good by the rains, not, as at present, drawn up and passed on to somewhere else. All rainy seasons will receive their proper rains, and during the dry season, when no depressions are about, the air will be sufficiently moist to allow vegetation to thrive without withering.

The following table will show what will probably happen when the Makarikari and Etosha lakes are reconstructed, on the assumption that the moisture in the atmosphere will induce as much again from the sea-borne winds that now fail to deliver their rain owing to droughty conditions:—

Table showing probable increase of moisture by reason of the evaporation from the Kalahari lakes.

1st year—2.5 million million c. ft.

2nd year—2.5 m. m. c. ft. engender 2.5 m. m. c. ft. from transpiration and precipitation of sea-borne clouds; flow of Cunene and Okavango-Chobe Rivers increased 10 per cent. Total for the year: 7.7. m. m. c. ft.

3rd year—7.7 m. m. c. ft. produce 7.7 m. m. c. ft. extra; flow of rivers, 3. Total: 18.4 m. m. c. ft.

4th year—	,,	36.1	,,	,,
5th year—	,,	75.8	,,	,,
6th year—	,,	155.8	,,	,,

There are too many uncertain factors to be reckoned with to make the calculation of any exactitude, but from the fact that more moisture will remain and circulate the more there are internal sources of supply, this table is more nearly correct than the previous one. What actually will happen is that the whole of the water in the first year will be either evaporated at once from the reservoirs, or if part of the water

is short-circuited past the depressions and led on to irrigated land, then the transpiration from the growing crops will give out an equivalent amount of water. The sum total being the same. Suppose the air in the Kalahari at the time has a humidity of 50 per cent., a value which I believe is appropriate, considering the readings of the wet and dry bulb thermometers at Ondongua; then twice the amount of rain will fall that would have done so without the reinforcement, simply from the reprecipitation of the transpired or evaporated moisture. In addition, all the dry thunderstorms that pass over to burst elsewhere will have effect, and the rainfall will be three times the present amount. It has been 9 inches in Ovamboland lately; 27 inches is not too much for this country, and it amounted to 36 inches in 1908-09. Let us take 12 inches for simplicity's sake.

Extra rain from evaporation, etc., over the Kalahari basin.

	Million Million c. feet.
Second year—	
Extra 12 inches from evaporation, etc., over 100,000 square miles ...	2.7
Induced from sea-borne clouds that would have otherwise have drifted away	2.7
Total increment from the Kalahari lakes, 2nd year	5.4
Third year—	
Extra 12 inches from evaporation, etc., over 300,000 square miles ...	7.1
Induced	7.1
	14.2
Fourth year—	
Extra 12 inches from evaporation, etc., over 700,000 square miles ...	18.9
Induced	18.9
	37.8

The figures could be made to equal those in the previous table by adjusting the square mileage on which the rain fell, but the correspondence is near enough. If these figures are right, then in the fourth year, 700,000 square miles, with an average rainfall of 5 inches, mostly Kalahari, will receive an extra 24 inches, and the land without irrigation will become suitable for growing sugar, cotton, coffee, and similar tropical products. This result will only happen if irrigation from the Makarikari is undertaken along with the storage of water. The Kalahari is most eminently suited for agriculture, more so than Egypt, because when the whole of the water-ways are in working order there will be no desert to induce brak and to scorch up the crops.

The following table shows the rotation of crops in Egypt, as a sample of what could be done in the Kalahari.

Rotation of Egyptian Crops and times of harvesting.

	Sown.	S. African equivalent.	Harvested.	S. African equivalent.
Winter crops—				
Wheat, barley, lentils, peas, beans, flax, lupins, clover ...	November. to December.	May to June.	April to June.	October. to December.
Summer crops—				
Cotton, rice, sugar-cane, mealies, indigo.	March, April, May.	September, October, November.	October to November.	April to May.
Autumn crops—				
Sorghum, durhha, Kaffir corn	July.	January.	November.	May.

The heat of the country is alleged to be so great in summer that it would not be fit for white men; certainly the heat is very great, and on one occasion I travelled 150 miles in the month of January in an open Scotch cart, and nearly succumbed. At night-time, however, I used a heavy double blanket to keep myself warm, and the heat is really not too great if proper houses are built. With greater moisture it will be more temperate in the day-time and warmer at nights, owing to the absorption of heat by the vapour in the atmosphere.

The malaria trouble is one that will disappear when the swamps are done away with and clear channels established.

The amounts given for the flow of the rivers takes no account of the seepage in the swamps, which is at present very great. A few places are known where the river is blocked, and these will have to be cut through; as the country is more and more inhabited, other works of a similar nature will be executed, and the whole run of the rivers brought under control. The Panama construction showed, once and for all, that malaria and other tropical diseases are pioneer troubles; they are amenable to treatment.

Capacity of the Makarikari and Etosha Pan, at depth of ten feet.

One square mile equals 27,561,600 sq. feet:

Area of Makarikari ...	15,000	sq. miles.
,, Etosha Pan ...	5,000	,,
Total	20,000	,,

Therefore the two lakes will hold 5,512,320,000,000, or 5.5 million million cubic feet with ten feet of water.

The reservoirs will only receive a little less than half this supply the first year, but with the increase of the flow of the principal rivers and the starting of the large dry rivers, like the Shua and Epukiro, there is no fear that in a few years the supply will not be sufficient to give the lakes more than ten feet of water. As the evaporation on the Gatun Lake, Panama, is about 90 inches, I do not think that it is ever likely to exceed, say, 7 or 8 feet in these lakes, so that, as long as the supply is more than the evaporation, the lakes will be permanent.

I have described previously how the floods of the Okavango are entangled in the swamps of the Teoghe, as the river is called where it emerges on to the bed of the old lake bed, and how Major Gibbons found the waters slowly forcing their way down the Selinda branch. It is characteristic of the whole of this flat country, that the rivers seem not to flow in the ordinary sense of the word, but great masses of water infiltrate the country, filling all depressions, and then

remaining stationary. If now the main channel of the Teoghe were to be opened by dredging in front of the oncoming flood, the river would pursue its old course, and flow more strongly, till the amount delivered into the Makarikari approximated that given in the estimates. When the lower courses were freed, then the flood plains of the reaches above Andara would become permanently dry land, and could be used either for native settlement or for white immigrants; the Upper Okavango is, however, not a white man's country. People in this climate degenerate, and become almost natives in their outlook. I should prefer to see the white settlements confined to the Kalahari, both in the Protectorate and in the Union.

There are two criticisms that I should like to deal with here, arising out of the above figures; they have been made not by any means by people who are in other ways stupid. The first is the remark that I have heard universally in the Cape. "What a pity one cannot find a scheme like this nearer our own place." Twenty-five years ago I did conceive a project to weir up all the rivers that come down from the Nieuwveld, and pass through a series of poorts in the foot hills, before they open out on the plains that stretch between the Matjesfontein-Beaufort West railway line and Moordenaars Karroo. An almost continuous line of great dams would result that would fill in favourable seasons, and once started, the natural circulation within the basin would keep them filled. The cost would have been, at a guess, £5,000,000, and I think there is a possibility of the ground increasing in value to the amount that would more than cover the outlay. The result would have been another experiment, which might or might not have succeeded, and the benefit would have been local. In the Kalahari scheme we obtain a vastly greater effect with less cost, and the size of the undertaking is such that the water-vapour will permeate the whole of South Africa, within the hedge of the coastal mountains. We shall find the inland slopes of these mountains giving as copious springs as the seaward slopes; these will gather into rivers and flow into the Karroo, as they did till quite recently. I have myself seen the mountains of Uniondale and Willowmore becoming drier and drier on the inland side in the

quarter of a century that I have observed them. Generally, I think I have made the case clear that the Kalahari scheme will yield results right throughout the Union; if we like to put it that way, it will increase the rainfall by 10 inches throughout. I leave it to farmers to estimate what the immediate benefit this will be to them and the actual money value, in the increased value of their farms, and carrying power of their veld, that will accrue; and it must be remembered that this increased rainfall will not be sporadic, but will be permanent.

The other criticism was a remark made to me in 1917, after the heavy rains of that year. I was told that if the farmers in the western Transvaal heard that I was going to increase their rain, they would shoot me. No one who lives in South Africa or in any of the arid regions of the globe will be deceived by this argument. Deluges are the result of violent disturbances of the atmosphere, and can only occur where there are desert or semi-desert conditions. When the air is reasonably supplied with moisture the tension is relieved as it arises, and seasonal and good, but not excessive, rains fall. The damage of our deluges is due first to the fact that the land becomes so dry and parched, that the run-off goes down to 1 per cent.; this means that all the water, practically, sinks in and turns the surface into a mud. If the torrential downpour is continued, the whole surface is washed out. Had the same amount of rain fallen over a longer period, the ground water would have received its quota, and when the rains continued, the excessive water would not have been absorbed, but would have run off in the stream beds. This brings in the second of the causes of damage, namely, that it is either a feast or a famine with us, and the feasts are of very short duration. Sudden bursts of rain fail to supply the underground waters and reinforce the springs, so that provision is not made for spells of dry weather. In a word, deluges are not found to occur in countries where there is an adequate rainfall.

I refer to these remarks in illustration of what the Kalahari scheme is capable of doing. All large projects have been subjected to the same criticisms; to quote only one,

the Suez Canal. British engineers reported against it, and were backed up by Lord Palmerston; even after it was actually built they refused to believe that it was practicable. Had it not been for the first English Rothschild, who bought a large block of shares, and induced Lord Beaconsfield to take them over for the British Government, England would have had no footing on the Canal, and probably in Egypt to-day. The creation of a larger Egypt in Africa by means of the Kalahari Scheme is going through the normal phases of all such projects; it is bound to come in the end, as South Africa cannot go on living on the mines, as it is doing to-day. The mines are finding that the task of paying for everyone in the Union is more than they can bear, and serious crises are continually happening. Agriculture, as it is at present constituted, is on an entirely artificial basis, and the abnormal markets have no elements of permanence; there is hardly a farm in South Africa which is secure; a drop in prices or a succession of bad years, and new owners take the place of the old ones. Apart from the direct irrigation lands in the Kalahari, the reconstruction of the ancient sources of supply will place every farmer in the Union on a new and better footing, and provide against the reintroduction of normal prices, which cannot be indefinitely postponed.

Settlement.

In the western half of the project, the "Efunja," or flooding of the country, will be revived, and the area will be unfit for white people to live in; besides, the country is densely inhabited, and with the removal of the checks to the increase of population caused by the droughts, the numbers of the Ovambos will soon double themselves. Good luck to them. At present the line of the division between Ovamboland and the settled districts of the South-West is the Ovambo River; south of the line is the Grootfontein Division, and north lies a waste area of extraordinarily beautiful country, that is, after the rains.

The country is white sand, with open spaces of grass covering the ground. Great trees of noble proportions stand in clumps, or arranged in natural avenues, with palms and

PLATE XIII. Morula Trees, Ondonga.

Otjimpolo River, dry for 60 years.
Teak Trees.

PLATE XIV. My Trek to the North.

Starting from Namutoni.

baobabs to bring in a sense of exotic conditions; otherwise, unless one looks closely to observe the species of the trees, one is lulled into imagining oneself in a specially magnificent park in England. Ponds every now and again are occupied by all sorts of birds, duck, teal, coots, herons and pelicans, as tame as if domesticated. There are a few German farmers on the south of the Ovambo River, west of Tsintsabis, but they are mostly people to whom legitimate farming would provide an inadequate living; if, however, the Ovambo River were to be full for any length of time, then cultivation and stock-breeding would afford quite a good livelihood. North of the Ovambo River, there is the Lion River, communicating probably with the Etosha Pan at Andoni; certainly the only decent water between Namutoni and Ondongua is found in the wells at Andoni. We have seen earlier, that these water-wells and oases in the desert are almost invariably on the track of a bygone river, and it is highly probable that when the Etosha Pan is full, there will be a permanent waterway between Andoni and the Okavango River. All this area might be settled, if it is deemed advisable to bring white men into these Lotus Lands. Still further north, there is the Hyaena River, which probably will connect with Kambonde's Vley when the water is restored to the country, and thus, through the Otjimpolo River, with the Etosha Pan. This part will depend how high the Okavango River will rise when reinforced by the increased rainfall on the Angola Highlands; there is no reason to suppose that it will not suffice to feed the spill-ways into this half of the Ovamboland Plain. North of the town of Grootfontein there are a few farms where cultivation is carried on, mostly mealies, but an Italian has a vineyard, and grapes appear to do well. This area is on the Otavi Dolomite, from the weathering of which there results a chocolate soil that has some substance. To the east of Grootfontein the country becomes sandy, and there appears to be something wanting in the soil, so that ordinary European crops fail. I think the principal reason is the enormous evaporation due to the desert around, so that the young plants become scorched, and this naturally would disappear when there was a permanent stream down the Ovambo River, and plenty of pools retaining flood-water to refresh the

air. If the former rainfall were to be restored, then all along the Ovambo River on both sides there would be admirable ground for settlement, and I image that sugar would do well here. The ground is so interspersed with hollows, sometimes manifestly abandoned river-channels, at others isolated pools and simply flat stretches between accumulations of sand, that I doubt whether any irrigation canals could be constructed to serve this area.

The distance from Namutoni to the embouchure of the Omatako River, past Tsintsabis and Gasamas, is about 230 miles. From Andoni to the mouth of the Lion River is about 145 miles. These two water-ways would serve country about 100 miles deep and allow for settlement for stock farming and tropical crops, mahongo, beans, and probably sugar. In its present condition the country is a waste, but with the rivers restored, it could be parcelled out into farms of reasonable size, say, 600 acres, and support a very large population. One of the consequences of making the Etosha Pan a permanent sheet of water would be to make the Omatako a more or less permanent stream, and settlement and irrigation could be carried out along the banks to a very large extent; for nearly 200 miles from the source, the river is fairly steeply graded, and canals could easily be taken out from it. It is, however, not my purpose here to enquire into the secondary effects of the restoration of the old water-system; there is enough to go on with in the actual benefits in sight, and it does not want much imagination to fill in the details of what will happen to the adjoining country when the desert places are made to blossom into cultivated gardens.

To summarise, there is room for 15,000 to 20,000 families of settlers, of a type that likes tropical conditions, and is not afraid of malaria, to find adequate ground in the Grootfontein and northern district, when the Etosha Pan is restored to its original condition. The wandering Bushmen will find it hard to restrain their hunting expeditions, but gradually some of them will become accustomed to service with Europeans; when young they make admirable house-boys and grooms; and for the rest, it will be many a long year before the 300,000 square miles of the Kalahari become filled, and the natural domain of the Bushmen turned into farms.

Bechuanaland.

The word "Bechuanaland" was first used by Lichtenstein, 1803-1806, but is not recognised by the inhabitants. The country comprises two unequal halves, a southern half that became part of the old Colony of the Cape of Good Hope in 1895, and the northern half, that has had a somewhat varied career. A Protectorate was first proclaimed over the territory by the High Commissioner in 1885, up to 22 degrees S. lat., right through the centre of Khama's country. In 1890 there was an Anglo-German agreement giving Germany access to the Zambesi through the Caprivi Zipfel, but incorporating the rest of the country up to the Zambesi. The British South Africa Company were given a block of the northern territory about Lake Ngami, but have never administered it. When the railway was built to Bulawayo, a "corridor," 10 miles wide, was given to the Rhodesian Railways, through the territory. Two Boer Republics were established in the eighties on the east, Stellaland, from the "star" or great comet of 1882, and Goshen; Sir Charles Warren was sent out on an expedition, and proclaimed the area as British in 1885.

The population of the northern Protectorate numbers 125,350, of whom 1,692 are Europeans. The following tribes are represented, with the approximate number of the natives.

Table of the chief Bechuana Tribes and approximate numbers.

BAMAGNWATO.—35,000. Chief, Khama. Capital, Serowe. Territory: from the Bakwena country on the south, to the Zambesi.

BAKHATLA.—11,000. Chief, Lenchwe. Gamcohopa district, north of Kanya.

BAKWENA.—13,000. Chief, Sebele II. Capital, Molopolele. Territory: from the Bawanketsi territory north to the tropic of Capricorn, and from the Notwani River north-west to Andersson's Vley.

BAWANKETSI.—18,000. Acting Chief, Kgosimotse, during minority of Bathoen. Territory: from the Molopo to the Metsimashwani tributary of the Notwani River. Capital, Kanya.

BATAWANA.—15,000. Chief, Mathibi. Territory: Ngamiland. Capital, Tsao.

MAKOBA.—Dependants of the last.

MANANSA and MASHAPETTANA. — South bank of Zambesi.

MADENASSA. — Makarikari. Bushmen-Bechuana half-breeds.

BANAJOA.—Mababe swamps.

BASILIKA.—East of Shoshong, near the Limpopo.

BACHWAPENG.—Adjoining the last.

BAROTSE.—Head-waters of the Molopo and Marico; also in the Zambesi Valley above the confluence of the Chobe. Capital, Lialui.

BASAOMAKA.—Griqualand West to Kuruman and Taungs.

BATLARO.—Ibidem. These two tribes now united with the Batlapin.

BATLAPIN.—Chief, Mankoroane. Capital, Taungs.

BARALONG.—Chief, Montsioa. Capital, Mafeking. Territory: between Vryburg and the Molopo River, with hunting grounds far to the west.

Other Tribes:

MAMPUKUSHU.—Ovambos, on lower Okavango.

BAYEYE.—Bantu, from Nyasaland. Lake Ngami.

BALALA.—Needy Bechuana, driven by poverty into the desert.

SANQUAS.—True Bushmen.

KHOI-KHOIN.—Hottentots, in the south about the bend of the Nosob.

BASTARDS.—Half-castes, similar to those in South-West Africa. From the Nosob, south to the Orange River.

KORANNAS.—Hottentots; from the bend of the Orange River to the Aughrabies Falls.

The natives have first right to the ground, and any scheme for irrigation must first of all make ample provision for them. We do not want to see repeated what has hap-

pened in other parts of South Africa, that is, small reserves for the natives surrounded by white farms. The Kalahari is big enough to set apart whole blocks for native occupation, without disturbing them in their present habitats; in exchange, however, for their vast hunting fields, lands under irrigation might be assigned to them, and there would then no longer be famine and water scarcity among them, a condition of affairs that is increasing, and which they will do anything so that the conditions may be improved.

No titles to land have been given to white men in the Protectorate, and the negotiations requisite for settlement will have to be very carefully dealt with. It is impossible to state now where the water will flow; the channels are sanded up, and only bits of the rivers appear here and there. It would be sufficient for the first few years of the working of the scheme to obtain right of way through the Protectorate for the water-channels. The lay-out of the ground to be irrigated must be subordinate to Imperial politics, and the ratio between native land and land to be given out for white settlement is a matter which cannot be touched on here. All I can say is that, whether the water is short-circuited past the Makarikari or derived from the overflow of this lake, there are lands in sight to which the water could be led of about 250 miles from the end of the Botletle River to the Molopo River, and an additional 250 miles from Andersson's Vley to the Nosob; on the Protectorate side, in addition, there are 225 miles on the north of the Molopo River, and 100 miles on the east of the Nosob River. Judging from the enormous flood plains along these rivers, an average of ten miles on either side of the river would not be excessive to take as the area to which the water could eventually be led. This gives an area of 13,250 square miles to which water, if it is available, could be led. One block of 1,000 square miles might be developed at first, reserving the right to take up, say, further blocks of 1,000 square miles at intervals as required. The significance of the figures is that they completely dispel the fear expressed by some people, that this irrigation scheme will cause trouble with the natives; the country is so vast that they need not come in contact with the white settlements at all. 1,000 square miles is 640,000

acres. In previous publications I have taken 600,000 acres as the effective area, the rest serving for roads, townships, etc. This allowance is, I believe, too little, and at least 10 per cent. should be allowed, but the difference is not worth considering in these preliminary estimates.

There are two charges against irrigation lands of this nature: (1) the amount assessed against the plots to pay for the main construction, and the channel conveying the principal stream. This is a capital charge, which must be recovered from the purchase price of the plots. (2) The other charge is for the special leading to the particular plot, together with maintenance of the whole. This is an annual charge that should come out of the water-rates paid by the owner of the plot; the two require careful consideration.

The purchase price of the irrigated plot must have some relation to an ordinary investment. If a man puts £1,000 into stocks and shares, he expects to obtain 5 or 6 per cent., or if it is into a business, 10 to 12 per cent., and he can earn a livelihood as well. Take as a unit a 100 acre farm. A net return per acre may be stated in normal times in terms of the staple crop of South Africa, mealies, at £5 an acre. Income therefore £500, after paying expenses. The farmer's wages, to make the project attractive, should represent £400 a year, therefore there is £100 to represent the interest on his invested capital. Again, that the investment should be such as will attract people, the interest should be at least 10 per cent. Hence we arrive at a figure of £1,000 for the 100 acre farm, or £10 an acre.

The one block of 1,000 square miles, when fully occupied, will represent, taking it as 600,000 acres for actual allotment, at £10 an acre, £6,000,000—enough to pay for any construction, interest during development and contingencies. Also for the free gift of water to the native population, for the benefit of which they will be amenable to further developments. By such a scheme land can be offered to settlers in terms that will ensure occupation; there will be none of the hesitancy manifested by American farmers, who have to pay out from £35 to £50 per acre, and water-rates as well.

In the matter of water-rates, there are assets which will tend to reduce them. In the first place, a farming community with cheap land will soon be affluent, and will spend money freely. All this means prosperous townships and valuable trading rights which, if retained by the body responsible for the construction of the whole scheme, should go a long way towards furnishing a fund for improving the water distribution and lessening the charges. I do not here wish to go into the question of whether the body responsible should be either the Imperial Government, the Government of the Union, or a private company. In the last case trading rights will represent dividends, and the farmers will pay a little more for the necessary services and up-keep. I should in either case advise that the plots should be sold at a minimum price; the settlers then will become rich, and the loss in the purchase price of land will be more than recovered in the receipts from township and trading sites.

The scheme, considered from the Union point of view, is different. The actual lands available south of the boundary, are smaller, but sufficient to warrant action for this part of the scheme alone. The actual area is as follows:—from Scots Drift on the Molopo to the culvert on the Upington railway, 250 miles; from the bend of the Nosob to the junction, 100 miles. Breadth of flood plain on the Colonial side, 5 miles; total area available within the Union for irrigation, 1,750 square miles. If 750 square miles be reserved for Poor White settlement, there remains a block of 1,000 square miles, which, at the previous estimate, is worth to the Government at least £6,000,000, not counting the increased value of the grazing veld in proximity to permanent water, which is at present worth 6d. an acre.

Poor Whites.

The official estimate of the number of heads of families living in poverty among the rural population, is 27,000; if 20 acres are allotted to each, this, with grazing rights, will provide them with a living, so that, if all come into the scheme, 640,000 acres are requisite. Allowing for some who will not come, an estimate of 480,000 acres is adequate, that

is, 750 square miles. The cost of the whole movement should be on a self-supporting basis, as the only way to remedy the hopelessness of these wretched people is to force them to undertake responsibilities; it is no use doling out charity to them; I have had personal experience of this myself.

The reasons why I believe the Kalahari scheme will provide a solution of the Poor White question, where others have so conspicuously failed, are as follows: (1) Agriculture in this hot region is peculiarly suited to the impoverished constitutions of the people in question, as witness the success of the settlement at Kakamas, on the Orange River. Here, many of the hopeless cases have become self-respecting members of society, and some of them have become rich. (2) The ground so long fallow, is as rich as that in the Fayum, the most fertile region of the globe, and any directed effort, with a reasonable supply of water, is bound to be a success. There will not be the heart-breaking succession of droughts, that make the farmers feel that no effort on their part is of any use, for God, Nature, the country, and the Government all seem to be banded against the wretched farmer. (3) The third reason is the most important of all. Settlement schemes have been tried again and again on a small scale, and have not been a success. The persons in charge have been poorly paid, and have been glad to be shifted to other billets; there has not been that concentrated and continuous effort on the part of the people responsible for the management, without which success could not have been expected. The collection of Poor Whites assembled in these colonies has been fortuitous, and on the most economical basis. 97 families, at the Goedemoed Labour Colony, occupy 616 acres; this is not enough to provide the families with anything more than a very poor livelihood. The colonies are comparatively small, and the moderate success of some of the members is swamped by the indifference of the rest.

With a great scheme, such as the settlement of 750 square miles, officials can be obtained who, from sense of duty and by adequate pay, will have their hearts in the success of the scheme; it will be big enough to have an appreciable effect on the whole question of the Poor Whites, and if worked

properly, will solve the difficulty for all time, so that, to a conscientious official, it will be worth while. The administration of big assets allows for high salaries, so that, again, the officials will strive to do their best, less they be removed to less lucrative billets. The allowance of 20 acres to a family will provide more than a bare subsistence, and consequently the settlers will be able to save money to buy for themselves some of the comforts and amenities of civilised existence. Further, among such a number, some will respond handsomely, for it is not in human nature to be wholly bad, and the example of some who have made a real success of their lives after the submergence, will stimulate the others to do likewise, and in addition, those poorer in heart and mind will be caught in the wheels of the machine, and carried onward to success by the impetus of the great corporate movement, in spite of themselves. I well appreciate the difficulty of the redemption of the Poor Whites; they are sunk into such a hopeless state of degradation, looking to charity or crime to provide them with the necessaries of existence, and some even too listless to care whether they obtain these necessaries or not; they inter-marry and propogate their kind with such ease that their numbers, apart from the new recruits to the ranks that every year drop in, will become steadily greater. Professor Macmillan analysed the history of one family; one member, a labourer, himself one of 15, is father of 18; another, living in two appalling rooms, had a wife and eight children; two or three of the original family hold small portions of the family estate and are solvent, but an indefinite number of families, probably twenty, live in the neighbourhood as bijwoners. One of the members who possesses part of the farm that belonged to the grandparents, maintains two sons, two sons-in-law and their families, a feeble-minded daughter, twenty-four "souls" in all; the extent of the portion of the family estate owned by them is 400 acres, of which 4 acres are irrigable, but the soil is very poor.

From what I have seen, however, in the Industrial Schools, the children are amenable to discipline and instruction, and if the people are given a hope of recovering their self-respect and are driven by intelligent management, an

integral part of the white population of South Africa may be saved from starvation. That they wish to do something is shown in their coming forward for positions in the railways and mines, but they are not the stamp of men for these jobs. It would be far better to develop the side for which they are by nature and inheritance, best fitted, namely farming, and allow immigrants from abroad, who on their side are fitted by their nature and their inheritance for industrial pursuits, to take up the work in towns and on the railways.

White Settlement.

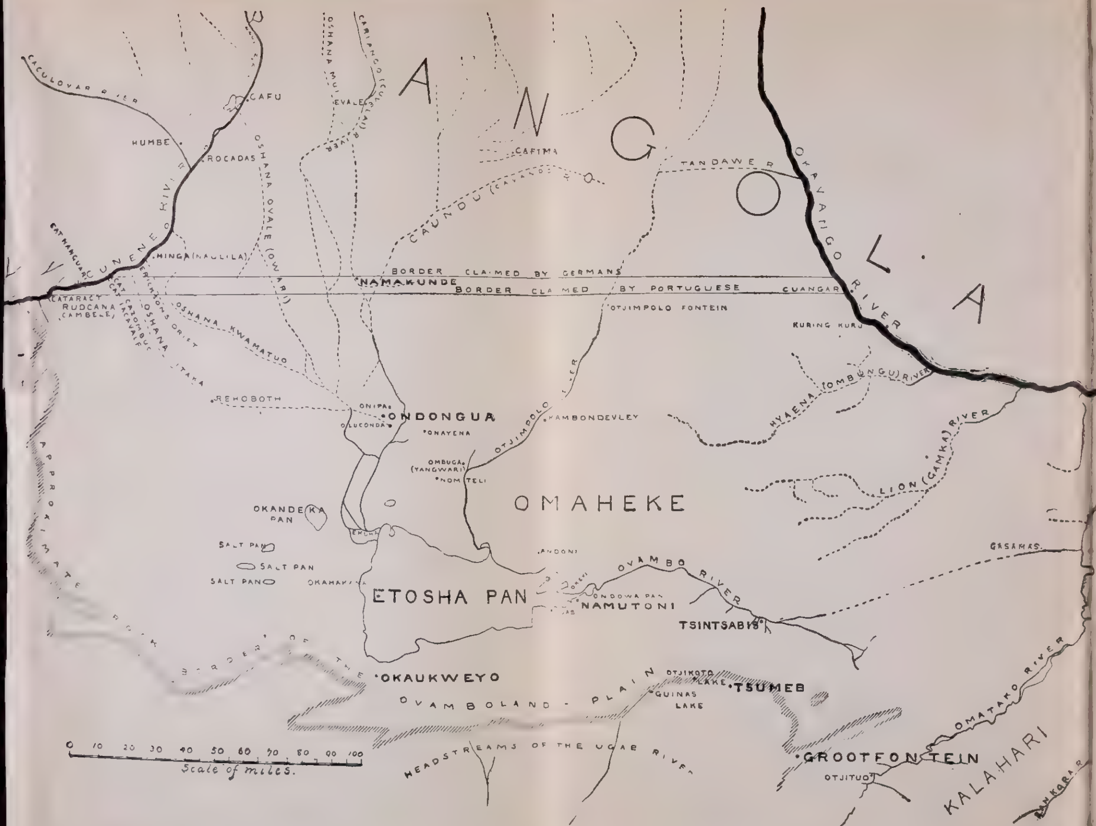
With a prospective £6,000,000 for the purchase of every 1,000 square miles of Kalahari, which is valued at present at from £15,000 to £30,000, the body, whether Government or private, could afford to give long credits. To work a 100 acres farm with full benefit, and with the comforts that should be at the command of every farmer taking up land in this region, there would be required a capital of £2,500, £1,000 for the purchase price of l and, £1,000 for house, farm-buildings, silo, etc., and £500 for stock and implements. I have put the minimum return at £500, but this is merely for mealies, which only require a plough and team of oxen; with stock, dairy, or otherwise, and with more payable lines of agriculture, such as tobacco, ground nuts, linseed and flax, and an indefinite number of similar lines, and the necessary capital to thoroughly go in for the particular crop under expert advice, the returns should be very much greater. At any rate, with good and bad seasons taken into consideration, the ordinary settler should be able to borrow and pay back in ten years a sum of £2,500. A good manager should be able to do so much sooner, but in a big affair such as is contemplated, the good people will not be in the majority.

It will be essential to the scheme for the directing body to have an experimental station, with a number of experts, who will be at the service of the settlers, and who will advise the management as to whether the settlers are profitably working their farms. With this safeguard, there is no reason why the settler should put up any capital at all; if he has capital, and he chooses to put it into his farm, then he

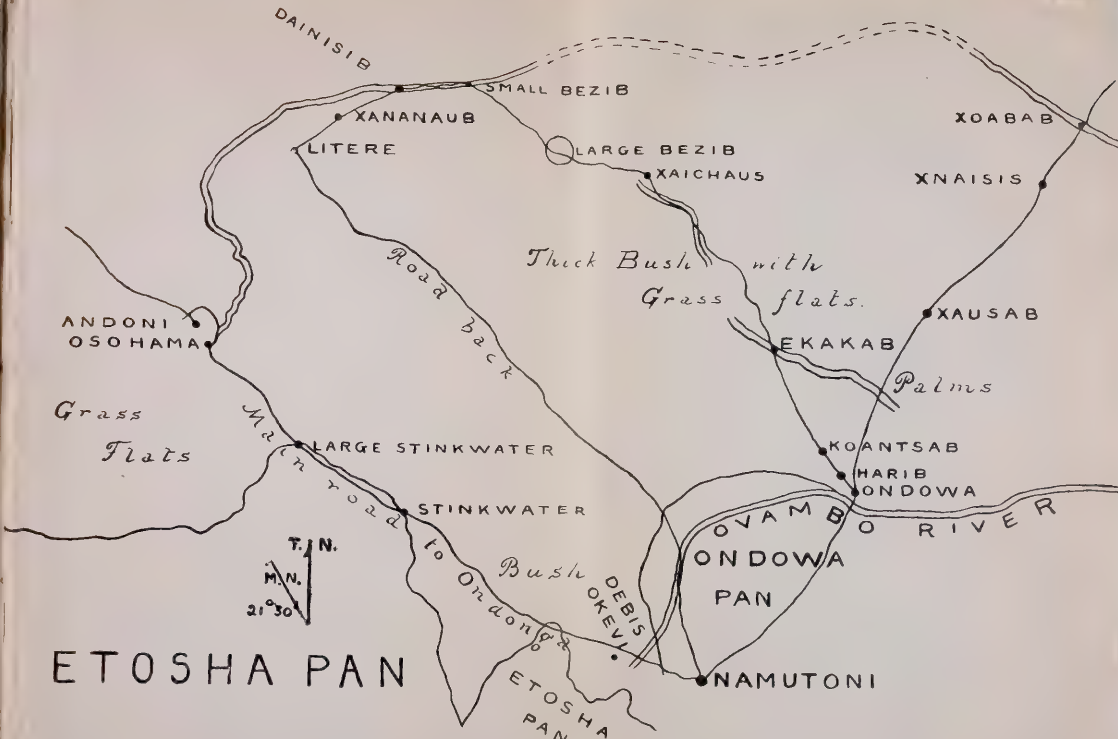
should obtain market rates of interest. It is only when doing things on a large scale and making use of the channels and depressions already provided by Nature, that irrigation farming can be pursued under such advantageous conditions. All the present irrigation projects are bound to go through the cycle of bankruptcy that they have in America, only a percentage of the most energetic and lucky individuals surviving; there will consequently arise a set-back, and people will decry irrigation in any shape or form. The principles that I have laid down will enable settlers to make comfortable livings, and those who are unsuccessful on other schemes will have an opportunity of retrieving their fortunes on this one.

In regard to accessibility, railways surround the area on the south and east. On the south there is the Upington-Nakop railway, connecting the Cape-to-Johannesburg line at De Aar with the ports of Luderitzbucht and Walvis. On the east there is the main line to the north from Kimberley to the Victoria Falls. From the latter, tributary lines could be run to the west, tapping the blocks of settlements as they become established; while from Upington a trunk line could be run all along the Molopo up to Ngami, serving the settlements. These lines cross no mountains, and the channels of the rivers will be of moderate width, so that there are no difficulties with the construction; they can be built cheaply, and just as fast as the traffic warrants them. In the early stages, before it is possible to build the railways, there are bad areas of sand to traverse; with motor transport, however, there is nowadays no difficulty. Motor-cars run up from Windhuk, right across the sand of Ovamboland to the Cunene, and the ever-memorable Kalahari expedition once and for all dispelled the bogey of transport across the Kalahari.

THE STANDARD PRESS, CAPE TOWN.


ANGOLA
CACULOVAR RIVER
CAFU
HUMBE
ROCADAS
CUNENE RIVER
EVALE
CAFIMA
TANDAWE R.
OKAVANGO RIVER
CAUNDU (CAVANGO) R.
MINGA (NAULILA)
BORDER CLAIMED BY GERMANS
NAMAKUNDE
BORDER CLAIMED BY PORTUGUESE
CUANGAR
CATARACT RUDCANA (CAMBELE)
OTJIMPOLO FONTEIN
KURING KURU
OSHANA KWAMATUO
REHOBOTH
ONIPA
ONDONGUA
OLUCONDA
ONAYENA
KAMBONDEVLEY
OTJIMPOLO RIVER
HYAENA (OMBUNGU) RIVER
OMBUGA (YANGWARI)
NOMTELI
LION (GAMKA) RIVER
OMAHEKE
OKANDEKA PAN
SALT PAN
SALT PAN
SALT PAN
ANDONI
OVAMBO RIVER
GASAMAS
ETOSHA PAN
ONDOWA PAN
NAMUTONI
TSINTSABIS
APPROXIMATE BORDER OF THE
OKAUKWEYO
OVAMBOLAND - PLAIN
OTJIKOTO LAKE
TSUMEB
GUINAS LAKE
0 10 20 30 40 50 60 70 80 90 100
Scale of miles.
HEADSTREAMS OF THE UGAB RIVER
GROOTFONTEIN
OTJITUO
OMATAKO RIVER
KALAHARI

MAP II.



MAP III. Patrol Map by J. W. F. Breijer, Ranger, Game Reserve, Namutoni.